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THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume I

Physical Damage Division

May 1947

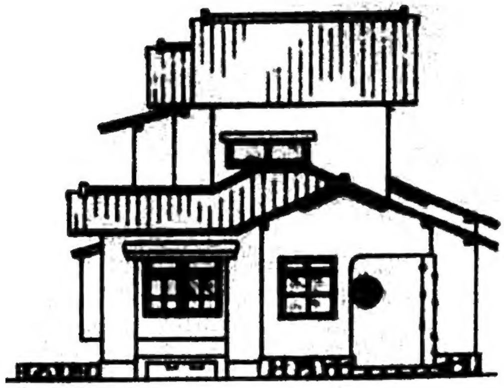
[redacted]

G. CAUSE AND EXTENT OF FIRE

1. Conditions Prior to Attack

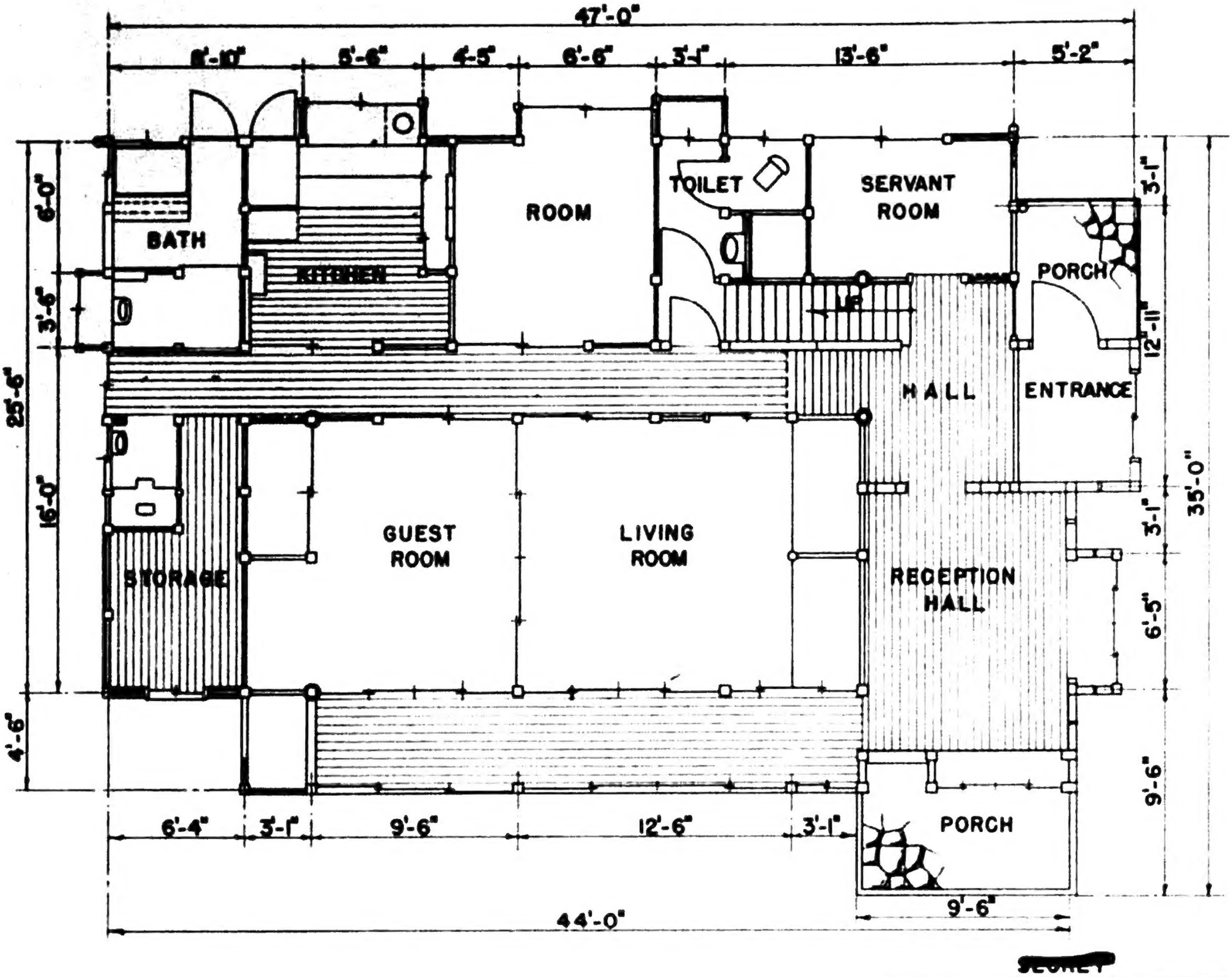
The city of Hiroshima was an excellent target for the atomic bomb from a fire standpoint: There had been no rain for three weeks; the city was highly combustible, consisting principally of Japanese domestic-type structures; it was constructed over flat terrain; and 13 square miles (including streets) of the 26.5-square-mile city was more than 5 percent built up (i. e., covered by plan areas of buildings). The remainder of the city comprised water areas, parks and areas built up below 5 percent. Sixty-eight percent of the 13-square-mile area was 27 to 42 percent built up and the 4-square-mile city center was particularly dense, 93.6 percent of it being 27 to 42 percent built up.

a. Fire Department. Public fire equipment had been little improved in anticipation of wartime fires. Private fire equipment had been augmented somewhat but instruction to home occupants in its use had been limited to training in combating incendiary bombs.



EAST ELEVATION

NORTH ELEVATION



· FIRST · FLOOR · PLAN ·

0' 5'

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U.S. STRATEGIC BOMBING SURVEY

TWO-STORY JAPANESE RESIDENCE

FIGURE 6-VIII

a. Evidence relative to ignition of combustible structures and materials by heat directly radiated by the atomic bomb and by other ignition sources developed the following: (1) The primary fire hazard was present in combustible materials and in fire-resistive buildings with unshielded wall openings; (2) six persons who had been in reinforced-concrete buildings within 3,200 feet of air zero stated that black cotton black-out curtains were ignited by radiant heat; (3) a few persons stated that thin rice paper, cedarbark roofs, thatched roofs, and tops of wooden poles were afire immediately after the explosion; (4) dark clothing was scorched, and, in some cases, reported to have burst into flame from flash heat; (5) but a large proportion of over 1,000 persons questioned was in agreement that a great majority of the original fires was started by debris falling on kitchen charcoal fires, by industrial process fires, or by electric short circuits.

b. Hundreds of fires were reported to have started in the center of the city within ten minutes after the explosion. Of the total number of buildings investigated 107 caught fire, and, in 69 instances, the probable cause of initial ignition of the buildings or their contents was established as follows: (1) 8 by direct radiated heat from the bomb (primary fire), (2) 8 by secondary sources and (3) 53 by fire spread from exposing buildings.

c. *Damage to Rolling Stock.* Of the 123 trolley cars operated by the company, 20 percent were damaged by fire and 45 percent by blast. Of the 85 motor busses, fire damaged 21 percent and blast 26 percent. Radiant heat from the bomb ignited cars and busses within 1,500 feet of GZ. Total damage to cars extended a maximum of 5,700 feet from GZ, heavy damage to 8,400 feet and slight damage to 12,500 feet. Busses were totally damaged at 4,000 feet and heavily damaged 5,500 feet from GZ.

d. *Damage to Overhead System.* Blast and fire damaged 11.4 miles of the overhead transmission system including damage to 500 wood and 100 steel poles. No damage occurred to concrete poles, the nearest of which were 6,000 feet from GZ. Wood poles were damaged at a maximum distance of 4,500 feet from GZ, and steel poles at 3,500 feet. Overhead transmission cable was downed by blast at 8,000 feet.

3. Conditions on Morning of Attack

a. The morning of 6 August 1945 was clear with a small amount of clouds at high altitude. Wind was from the south with a velocity of about 4½ miles per hour. Visibility was 10 to 15 miles.

b. An air-raid "alert" was sounded throughout Hiroshima Prefecture at 0709 hours. Reports of the number of planes causing this alert were conflicting. The governor of the prefecture stated that four B–29s were sighted, while the Kure Naval District reported three large planes.

c. The aircraft apparently came out over Hiroshima from the direction of Bungo Suido and Kunisaki Peninsula, circled the city, and withdrew in the direction of Harima-Nada at 0725 hours. "All-clear" was sounded at 0731 hours.

d. The following circumstances account in part for the high number of casualties resulting from the atomic bomb:

(1) Only a few persons remained in the air-raid shelters after the "all-clear" sounded.

(2) No "alert" was sounded to announce the approach of the planes involved in the atomic-bomb attack.

(3) The explosion occurred during the morning rush hours when people had just arrived at work or were hurrying to their places of business. This concentrated the population in the center of the city where the principal business district was located.

(4) Many persons residing outside the city were present for reasons of business, travel and pleasure.

(5) National volunteer and school units were mobilized and engaged in evacuation operations.

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THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume II

Physical Damage Division

Dates of Survey:

14 October–26 November 1945

Date of Publication

May 1947

[redacted]

A. OBJECT OF STUDY

The object of this fire study was to determine the extent of fire in Hiroshima resulting from the explosion of the atomic bomb on 6 August 1945, and to analyze the contributing factors.

B. SUMMARY

This section presents a picture of factors pertaining to fire in Hiroshima before, during and after the atomic-bomb attack. Part C describes fire conditions prior to the attack and analyzes the effectiveness of precautionary fire measures; Part D relates the story of the fire; Part E presents a detailed analysis of fire in selected fire-resistive, noncombustible, and combustible buildings, and their contents; Part F discusses the cause and extent of fire in bridges; and Part G present conclusions and recommendations.

1. The city of Hiroshima, like other Japanese cities, was poorly prepared to combat a conflagration of large-scale proportions. Private fire equipment had been augmented and home occupants had been given limited instructions and training in combatting incendiary bombs. Public fire equipment had been little improved to fight wartime fires.

2. The public water system was fairly adequate for normal fire conditions, although pressure was very low on dead-end mains at the south end of the city. No improvements had been made for wartime emergencies.

3. The Ota River and its six branches divided the city into nine distinct areas. The river courses and 41,000 feet of firebreak lanes which had been prepared by removing combustible buildings on one or both sides of fairly wide streets formed an extensive network of firebreaks.

4. The city, consisting principally of Japanese domestic structures, was highly combustible and densely built up. Sixty-eight percent of the 13-square-mile city area was 27 to 42 percent built up and the 4-square-mile city center was particularly dense, 94 percent of it being 27 to 42 percent built up. All the large industrial plants were located on the south and southeast edges of the city.

5. Precautionary fire measures were ineffective largely because widespread damage was caused by blast, the populace suffered severe casualties, innumerable fires were started throughout the city on both sides of natural and man-made firebreaks, and the public fire department sustained almost a knock-out blow.

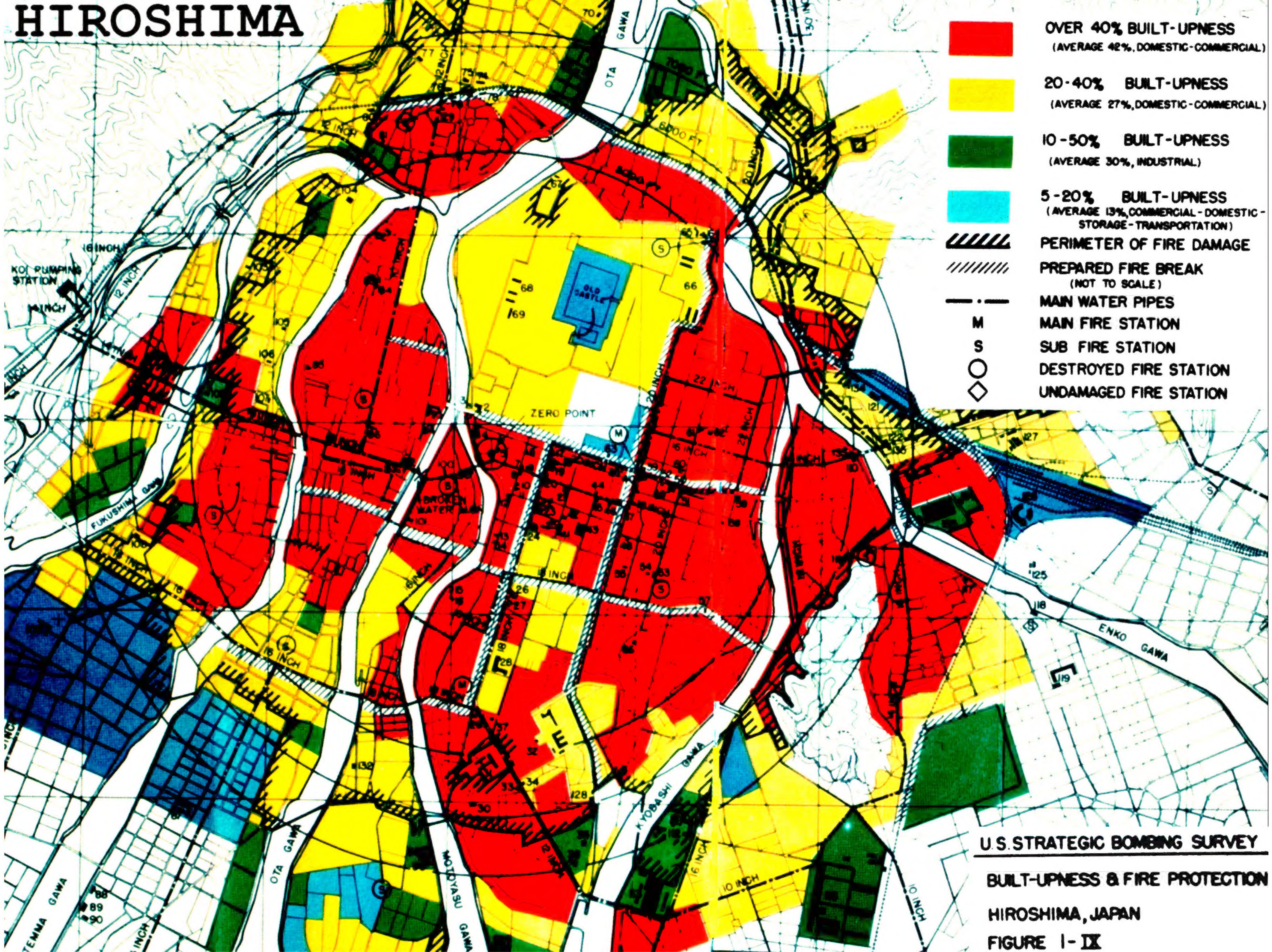
6. One major break occurred in a 16-inch water main when Bridge 29 which carried it was collapsed by blast. This and a large number of breaks in small pipes above ground in collapsed buildings reduced water pressure in the system, but the reservoir never ran dry and lack of water was not a factor in the extent of the fire.

7. The temperature resulting from the explosion of the atomic bomb was of great intensity but of extremely short duration. At ground zero, 2,000 feet from the center of heat, the temperature probably exceeded 3,500° C. for a fraction of a second. Only directly exposed surfaces were flash burned.

8. Evidence relative to ignition of combustible structures and materials by directly radiated heat from the atomic bomb and other ignition sources was obtained by interrogation and visual inspection of the entire city. Six persons who had been in reinforced-concrete buildings within 3,200 feet of air zero stated that black cotton black-out curtains were ignited by flash heat. A few persons stated that thin rice paper, cedarbark roofs, thatched roofs, and tops of wooden poles were afire immediately after the explosion. Dark clothing was scorched and, in some cases, was reported to have burst into flame from flash heat. A large proportion of over 1,000 persons questioned was, however, in agreement that a great majority of the original fires were started by debris falling on kitchen charcoal fires. Other sources of secondary fire were industrial-process fires and electric short circuits.

9. There had been practically no rain in the city for about 3 weeks. The velocity of the wind on the morning of the atomic-bomb attack was not more than 5 miles per hour. A fire storm, including both wind and rain, began to develop soon after the start of the initial fires. The fire wind, which blew always toward the burning area, reached a maximum velocity of 30 to 40 miles per hour 2 to 3 hours after the explosion, and intermittently light and heavy rain fell over the north and west portions of the city.

10. Hundreds of fires were reported to have started in the center of the city within 10 minutes after the explosion.


HIROSHIMA
OVER 40% BUILT-UPNESS
(AVERAGE 42%, DOMESTIC-COMMERCIAL)
20-40% BUILT-UPNESS
(AVERAGE 27%, DOMESTIC-COMMERCIAL)
10-50% BUILT-UPNESS
(AVERAGE 30%, INDUSTRIAL)
5-20% BUILT-UPNESS
(AVERAGE 13%, COMMERCIAL-DOMESTIC-STORAGE-TRANSPORTATION)
PERIMETER OF FIRE DAMAGE
PREPARED FIRE BREAK
(NOT TO SCALE)
MAIN WATER PIPES
M MAIN FIRE STATION
S SUB FIRE STATION
DESTROYED FIRE STATION
UNDAMAGED FIRE STATION
ZERO POINT
OLD CASTLE
KOI PUMPING STATION
OTA GAWA
ENKO GAWA
KYOBASHI GAWA
MOTOYASU GAWA
FUKUSHIMA GAWA
TEMMA GAWA
BROKEN WATER MAIN
U.S. STRATEGIC BOMBING SURVEY
BUILT-UPNESS & FIRE PROTECTION
HIROSHIMA, JAPAN
FIGURE I-IX

D. THE CONFLAGRATION

1. Start of Fire

a. Source of Evidence. Because of the practically total combustion which prevailed in the burned-over area of 4.4 square miles in the heart of the city, most of the evidence relative to ignition by radiant heat from the bomb and secondary sources of heat was necessarily obtained by interrogation which, wherever possible, was checked by field inspection. Also, since the heaviest casualties occurred closer in, a majority of the persons questioned were 3,000 feet or more from ground zero (GZ) at the time of the explosion. Most people who had been within 2,000 feet of GZ (2,800 feet from air zero) were utterly confused as to what had happened immediately after the detonation and for some time thereafter, although several were located who could give reasonably coherent stories. Because the distance of a point on the ground from air zero (AZ) was important from an ignition standpoint and the distance from GZ was important from a fire spread standpoint, the relationship between the two has been shown on Figure 2.

b. Direct Ignition by the Atomic Bomb. (1) Six persons were found who had been in reinforced-concrete buildings within 3,200 feet of AZ at the time of the explosion and who stated that black cotton black-out curtains were blazing a few seconds later. In two cases it was stated that thin rice paper on desks close to open windows facing AZ also burst into flame immediately, although heavier paper did not ignite. No incidents were recounted to the effect that furniture or similar objects within buildings were ignited directly by radiated heat from the bomb.

(2) Straw-thatched roofs were illegal within the city limits, but a number were erected outside. A few persons stated that they had seen this type of roof burst into flame directly from heat radiated by the bomb but the stories were inconsistent except in two instances where the persons could point to specific building sites. Both of these locations were almost due north of AZ, the first approximately 12,700 feet and the second approximately 13,900 feet. Despite the strong eyewitness accounts of the persons interrogated, there is considerable doubt in the minds of the investigators that these buildings were ignited directly by radiated heat from the bomb. This doubt is predicated chiefly upon three considerations, namely: (1) Buildings, including many with straw-thatched roofs 3,200 feet nearer AZ (10,700 feet), suffered no fire damage; (2) farmers working in an open field only 800 feet beyond (14,700 feet) suffered no burns of any kind although they felt a wave of warm air pass over them almost simultaneously with the sound of the explosion; and (3) the roofs of these buildings collapsed as a result of the blast and may have been ignited by charcoal braziers.

(3) One dwelling which had a cedarbark-shingle covering that was reported ignited by the flash heat from the bomb was found approximately 6,700 feet northeast from AZ and slightly over 200 feet beyond the fringe of the burned-over area. This house was of the frame and stucco type common to the area and was one of several forming a small group within an enclosure formed by an 8-foot masonry and wood wall. All houses within the enclosure had tile-covered roofs, but one of the group also had a small section covered with highly inflammable cedarbark shingles which showed fire damage, although the fire had been extinguished before the entire roof was consumed (Photos 28 and 29). The owners of the property, including a son who was a university graduate, insisted that the roof covering burst into flame immediately with the bomb explosion. Their story could not be shaken. The chief of the fire department stated that he had heard of two or three cases where the cedarbark-covered roofs, also not permitted within the city limits, had been ignited directly by the bomb, and thought the reports credible. A number of buildings with unburned cedarbark roof shingles were found at a rayon plant approximately 11,000 feet southwest from AZ.

(4) About 600 feet east of the dwelling described above and about 365 feet from the nearest burned building, a wood pole which had apparently carried electric wires, probably 220 volts AC, was found with 3 to 4 feet of its top burned off and rather heavy flash burns on the side facing AZ (Photo 30). Several residents of the area stated that this pole had been seen burning about 5 or 10 minutes after the bomb explosion. It is entirely possible that ignition of this pole was caused directly by heat radiation from the bomb. The pole was capped with a light steel plate of dark color and it may be that the steel absorbed sufficient heat and retained it long enough to ignite dry rot which probably was present under the metal cap. An attempt to determine from utility company records whether or not the pole had been burned previously was unsuccessful. Many wood

poles within the fire perimeter were burned, but it is impossible to state with certainty whether the source of ignition was direct heat from the bomb or heat and flying embers from nearby buildings. Other evidence, however, leads to the conclusion that exposed wood was seldom ignited by radiated heat from the bomb.

(5) A cemetery about 2,500 feet from AZ was found cluttered with pieces of very light wood (excellent kindling) which showed no evidence of flash or other burns (Photo 31). It is believed that this debris must have been blown by the blast from the interior or other unexposed portions of structures and this accounts for the lack of flash-burn marks. It is interesting that none of this material was ignited by flying embers, as it was very close to the center of the burned-over area of the city. Photos 32 and 33 also show unburned combustible buildings at 3,800 and 5,000 feet from AZ.

(6) One of the graves in the cemetery was enclosed with a wood fence. The fence was composed of four corner poles extending about 30 inches above the ground and supporting two horizontal pieces, about 12 inches apart. Bamboo pickets (about 1½ by ⅜-inch) were lashed to the fence with vegetable-fibre rope. The corner poles showed deep charring which later proved to have been done according to Japanese custom when they were erected. The horizontal pieces apparently were not charred, but when the lashing for the pickets was removed very definite evidence of flash-burn showed. The bamboo pickets showed light flash-burn marks. The rope lashing for the pickets showed no evidence of having been on fire, but was singed.

(7) At the Red Cross Hospital, 5,300 feet south from AZ, three chairs with backs and seats upholstered with a pile fabric (apparently mohair) were near a window which was exposed to AZ. The backs of the chairs showed moderate to deep singeing except for the lower part which had been shielded by the concrete wall and showed no discoloration. Parts of the seats of the chairs showed light flash-burns where the seats had not been shielded by the chair backs. No part of the upholstery was burned through (Photo 34). Next to the chairs was a varnished wood door which showed definite evidence of flash-burn except for a very small spot adjacent to the door knob which shielded it. The door did not catch fire (Photo 35). A cotton jacket worn by one of the nurses was charred across one breast. The outer material of the jacket was burned away in part, but the padded cotton lining directly underneath was not burned through (Photo 35). The nurse who had worn the jacket was severely injured by the blast and was not available for questioning. It was stated that her body was not burned through the coat. Testimony at the hospital indicated that several coats had burned similarly, but the others could not be produced for examination. Furthermore, nobody at the hospital was certain that these coats had actually burst into flame, and, in fact, the concensus was that they had only smoldered. There was no other evidence of fire in the hospital.

(8) Scores of persons throughout all sections of the city were questioned concerning the ignition of clothing by the flash from the bomb. Replies were consistent that white silk seldom was affected, although black, and some other colored silk, charred and disintegrated. Numerous instances were reported in which designs in black or other dark colors on a white silk kimono were charred so that they fell out, but the white part was not affected. These statements were confirmed by United States medical officers who had been able to examine a number of kimonos available in a hospital. Ten school boys were located during the study who had been in school yards about 6,200 feet east and 7,000 feet west, respectively, from AZ. These boys had flash burns on the portions of their faces which had been directly exposed to rays of the bomb. The boys' stories were consistent to the effect that their clothing, apparently of cotton materials, "smoked," but did not burst into flame. Photo 36 shows a boy's coat that started to smolder from heat rays at 3,800 feet from AZ.

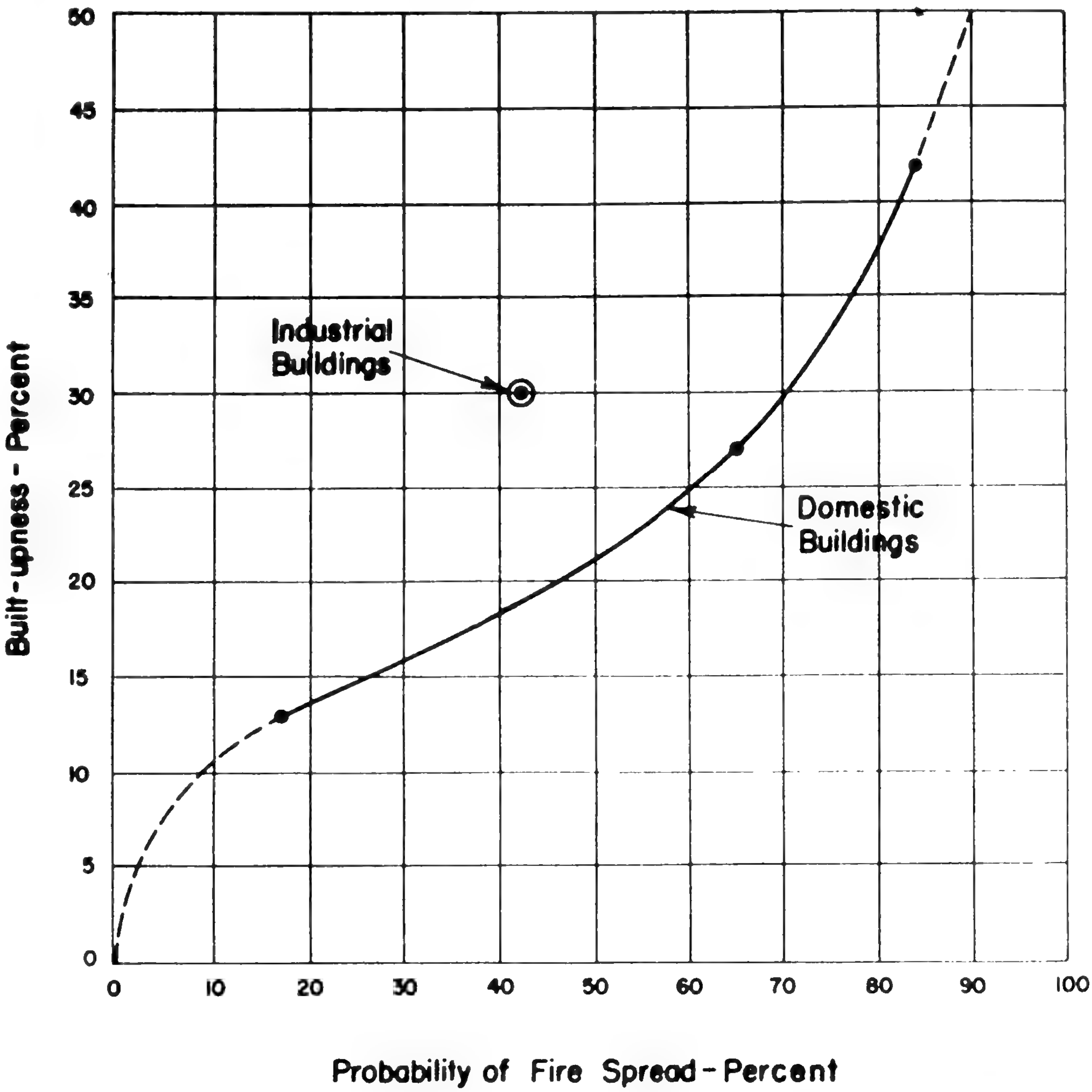
(9) Three automobile trucks, powered with internal combustion motors using fuel generated by burning charcoal (no gasoline or similar volatiles used), which were parked in a clearing about 7,800 feet north from AZ were said to have been ignited immediately after the bomb explosion. Fire damage to the vehicles was total. Conversely, however, a sedan showing no fire damage was examined where it had been abandoned as a result of severe blast damage on a wide street about 5,800 feet southeast from AZ.

(10) A private garden covering an area of slightly over 5 acres and located about 5,000 feet northeast from AZ showed no evidence of having been on fire, although there was some flash-burn damage on the edge of the area facing AZ.

PHOTO 36 IX. Shows partly burned coat of boy who was in open near City Hall (Building 28) 3,800 feet from AZ.

3800 feet from air zero;
3300 feet from ground zero

PROBABILITY OF FIRE SPREAD IN VARIOUS AMOUNTS OF BUILT-UPNESS



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U.S. STRATEGIC BOMBING SURVEY
FIRE SPREAD VS. BUILT-UPNESS
HIROSHIMA, JAPAN
FIGURE 4-IX

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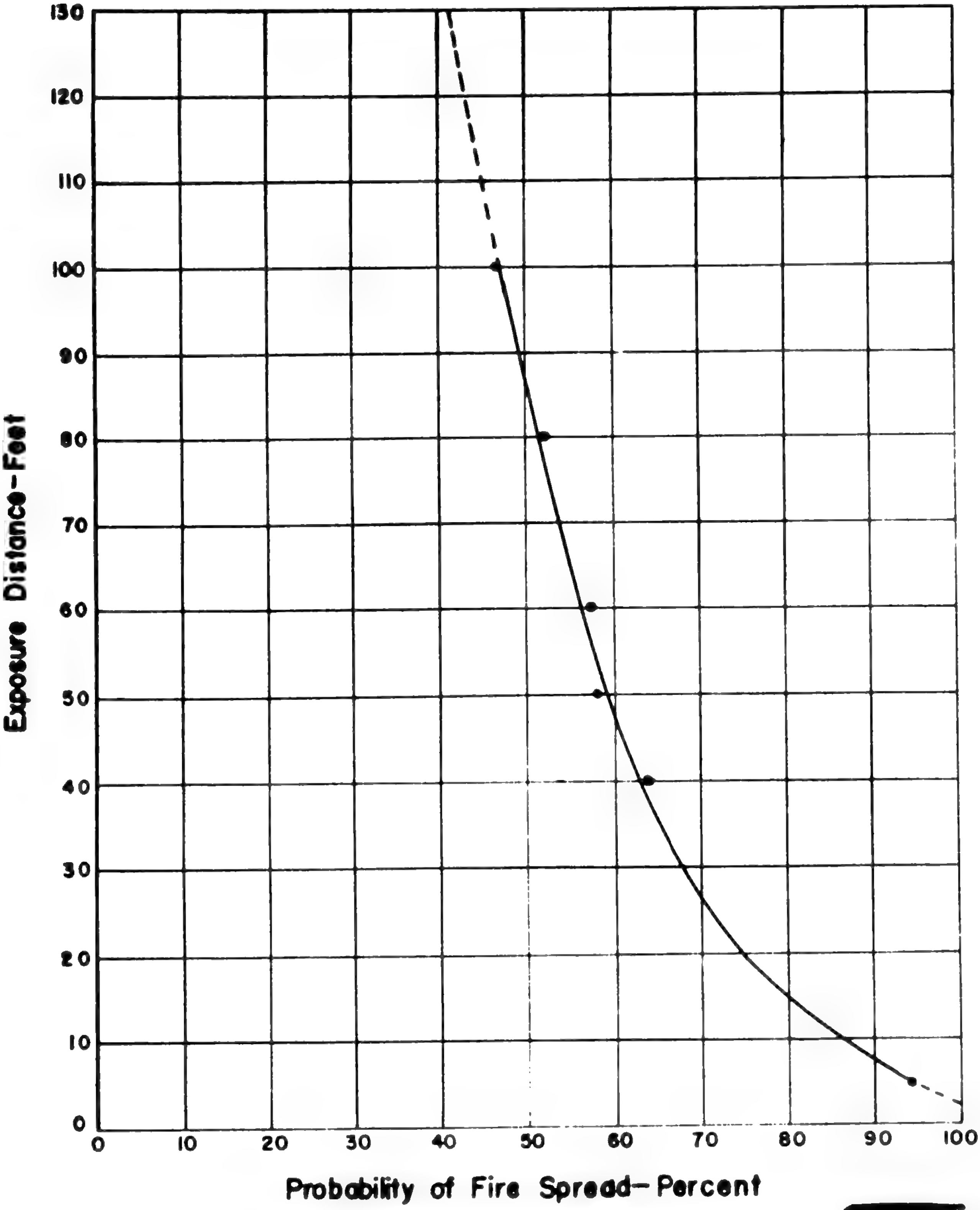
PROBABILITY OF FIRE SPREAD ACROSS VARIOUS EXPOSURE DISTANCES



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U. S. STRATEGIC BOMBING SURVEY
FIRE SPREAD VS. EXPOSURE DISTANCES HIROSHIMA, JAPAN FIGURE 5 - IX

TABLE 5.—*Fire-resistive building data (fire)*

Building No.	Coordinates	Distance from AZ (feet)	Distance from GZ (feet)	Occupancy	Fire shutters on wall openings	Unprotected wall openings exposed to AZ at zero hour	Distance from unprotected wall openings to nearest burned building (feet)	Probable cause of initial ignition	Number of stories	Stories burned (after blast damage)	Areas in thousands square feet		Percent floor area burned
											Total floor area	Floor area burned	
1	4H	2,100	700	Office	No	Yes	0		B-2	1-2	4.2	3.5	83
2	4H	2,100	800	do	No	Yes	20		B-3	60% B, 100% 1-3	27.3	24.3	89
6	5H	2,100	600	do	Yes	Probably no	10	Fire spread	B-3	70% B, 100% 1-3	16.6	15.3	92
7	5H	2,100	600	Bank	Yes	Yes	6	do	2	1-2	5.7	5.7	100
8	5H	2,100	600	do	Yes	Yes	10	do	3	1-3	9.0	9.0	100
9	5H	2,100	600	Office	Yes	Yes	10	do	B-3	1-3	4.9	4.2	86
10	5H	2,100	600	do	Yes	Yes	10	do	2	1-2	2.5	2.5	100
11	5H	2,100	700	do	No	Yes	30		3	1-3	9.8	9.8	100
12	5H	2,100	700	do	No	Yes	10		B-3	B-3	15.8	15.8	100
18	5H	2,200	1,000	Bank	Part	Probably no	10	Fire spread	B-5	B-5	46.4	46.4	100
19	5H	2,200	1,000	do	Yes	Yes	20	Primary	B-4	75% 1-2, 100% 3-4	29.9	25.2	84
20	5H	2,200	1,000	Office	Part	Yes	10		3	1-3	4.5	4.5	100
21	5H	2,300	1,300	Bank	Yes	Yes	15	Primary	2	1-2	7.3	7.3	100
22	5H	2,300	1,100	Office	Part	Yes	10		4	1-4	20.4	20.4	100
23	5H	2,300	1,200	do	No	Yes	10		B-7	1-7	43.3	39.0	90
24	5H	2,400	1,300	Bank	Yes	Yes	25	Fire spread	B-3	5% 2, 100% 3	32.8	5.2	16
25	5H	2,400	1,400	Art museum	Part	Yes	10		2	1-2	5.4	5.4	100
26	5H	3,000	2,300	Office	Part	Yes	10	Primary	B-5	40% B, 100% 1-5	52.0	46.5	88
27	6H	3,100	2,400	Library	Part	Yes	25		4	1-4	13.4	13.4	100
28	6H	3,800	3,300	Office	No	Yes	50	Fire spread	B-4	80% B-1, 100% 2-4	93.4	84.9	91
31	6H	5,300	4,900	Hospital	No	Yes	75	No fire	B-3	None	88.6	0	0
32A	6H	5,100	4,700	Classrooms	No	Yes	25	Fire spread	2	1-2	2.8	2.8	100
32B	6H	5,200	4,800	Library	Yes	No	5	do	2	1-2	3.7	3.7	100
32D	6H	5,000	4,600	Classrooms-laboratories	No	Yes	30	Secondary	3	1-3	103.3	103.3	100
32E	6H	4,700	4,200	Classrooms	No	Yes	30	Fire spread	3	1-3	39.5	39.5	100
32F	6H	5,000	4,600	Laboratory	No	Yes	12	do	1	1	2.0	2.0	100
32G	6H	5,200	4,800	Kitchen	No	Yes	0	do	1	None	3.0	3.0	0
32H	6H	5,300	4,900	Laboratory	No	Yes	6	do	2	1-2	3.8	3.8	100
33	6H	5,600	5,300	Office	Part	Yes	90	do	B-4	None	62.6	0	0
38	5H	2,900	2,100	do	No	Yes	20	do	B-3	B-3	10.4	10.4	100
39	5I	3,200	2,500	do	Part	Yes	10	Primary	4	1-4	32.0	32.0	100
40	5H	3,200	2,500	Department store	No	Yes	50	do	B-7	B-7	78.9	78.9	100
41	5H	2,600	1,700	Classrooms	No	Yes	20		B-3	75% B, 100% 1-3	26.4	25.1	95
43	5H	2,800	2,000	Telephone exchange	Part	Yes	35	Secondary	3	1-3	36.1	36.1	100
44	5H	2,700	1,800	Department store	Yes	Yes	5		3	1-3	4.3	4.3	100
45	5H	2,700	1,800	Bank	Yes	Yes	0		3	1-3	8.0	8.0	100
47	5H	3,100	2,300	Beer hall	No	Yes	20	Fire spread	B-3	1-3	15.3	13.2	86
48	5H	3,300	2,600	Hospital	No	Yes	6		2	1-2	2.9	2.9	100
49	5I	3,600	3,000	Office	Part	Yes	90	Primary	7	1-7	14.7	14.7	100
50	5I	3,600	3,000	Newspaper plant	No	Yes		Fire spread	3	1-3	24.5	24.5	100
51	5I	3,700	3,200	Bank	Part	Yes	40	Primary	B-3	15% B, 100% 1-3	26.7	19.2	72
59	5I	4,500	4,100	Office	Part	Yes	30	Fire spread	B-3	None	16.2	0	
61	5I	4,000	3,400	Radio station	No	Yes	15		2	1-2	8.3	8.3	100
62	5I	4,100	3,600	Residence	No	Yes	0		2	1-2	2.2	2.2	100
64	3I	5,300	4,900	Hospital	No	Yes	30	Primary	B-2	Second only	15.9	5.3	33
65	3I	5,300	4,900	Office	No	Yes	30	Fire spread	4	50% 1-3, 90% 4	83.4	50.0	60
67	3H	5,000	4,600	Munitions storage	Yes	No	125	No fire	1	None	1.7	0	0
74	3H	6,300	6,000	Electrical laboratory	No	Yes	30	Fire spread	B-2	70% B-1, 100% 2	13.2	10.6	80
76	3G	6,200	5,900	Warehouse	Yes	Yes	0	do	1	1	15.9	15.9	100
79	3G	6,100	5,800	do	Yes	Yes	6	do	2	1-2	14.4	14.4	100
85	4G	3,800	3,300	Telephone exchange	Yes	Probably no	125	Secondary	3	25% second only	14.2	1.1	8
86	5G	2,800	2,000	Classrooms	No	Probably no	125	No fire	3	None	11.5	0	0
93	5G	2,500	1,500	Warehouse	Yes	No	0	Fire spread	2	1-2	2.9	2.9	100
95	4G	2,300	1,200	Classrooms	No	Yes	30		B-3	B-3	49.5	49.5	100
96	5G	2,000	400	Clothing store	No	Yes	10		B-3	1-3	12.4	9.3	75
100	5G	2,100	800	Office	No	Yes	0		2	1-2	3.0	3.0	100
101	5G	2,600	1,700	Warehouse	Yes	Probably no	5	Fire spread	2	1-2	4.3	4.3	100
113O	7I	7,700	7,400	Cigarette manufacture	No	Yes	60	No fire	1	None	54.6	0	0
122	5J	6,700	6,400	Bank	Yes	Probably no	5	Fire spread	2	None	5.1	0	0
120	3G	6,000	5,600	do	No	Yes	12	No fire	B-2	None	16.2	0	0
132	6G	5,700	5,400	Warehouse	Yes	No	0	Fire spread	B-1	B-1	15.0	15.0	100
133	5J	6,200	5,900	Mercantile	No	Yes	0	do	4	1-4	3.0	3.0	100
134	4J	6,300	6,000	Office	Yes	Yes	60	do	3	80% 1, 100% 2-3	4.8	4.5	94
135	5J	6,800	6,500	Bank	Yes	Yes	100	No fire	B-2	None	9.0	0	0

SOURCE: USSBS's Secret report, "The Effects of the Atomic Bomb on Hiroshima, Japan," vol. 2   Only 8 of 64 non-wood buildings had thermal flash ignition evidence, 3 had blast damage induced fire, and 28 were ignited by firespread from wood homes.

(4) It was reported that a cotton black-out curtain at an unprotected window in the east stair tower of Building 85 (3,800 feet from AZ) smoked and was scorched by radiated heat from the bomb but it did not burst into flames. All windows other than those in the stair tower were protected by closed steel-roller shutters. There was fire damage in a few telephone relay units in the second story but this was caused by electrical short circuits when debris from windows was blown into the equipment by blast.

(5) A man who was in the third story of building 26 (3,000 feet from AZ) stated that radiated heat from the bomb ignited cotton black-out curtains at unprotected windows in the west wall and thin rice paper on desks. According to his recollection, all stories were afire five minutes after the attack. On the other hand, two men who were working in Building 28 (3,800 feet from AZ) stated that there was no primary fire in this building, the windows of which were not equipped with fire shutters. Black-out curtains at all windows were drawn back and no fires started in them. According to the same men, fire spread into the building by flying brands from the south nearly two hours after the attack.

(10) Fire fighting with water buckets was reported inside only four buildings (24, 33, 59, and 122) and probably prevented extensive fire damage in them. In Building 24, fire was started in contents of a room at the southwest corner of the second story by sparks from trees on the south side about 1½ hours after the attack. Men inside the building extinguished the fire and probably prevented further damage in the first and second stories (Photo 85). A little later, contents in the third story were ignited by sparks from the outside and were totally damaged. This fire was beyond control before it was discovered, but did not spread downward through open stairs. At Building 33, sparks from the west exposure, which burned in early evening, set fire to black-out curtains in the west wall and to waste paper in the fourth story of the northwest section of the building. Twenty persons were on guard in the building awaiting such an occurrence and the fires were quickly extinguished while in the incipient stage. At Building 59 sparks from the south exposure ignited a few pieces of furniture in the first and third stories and black-out curtains in the first story about 2 hours after the attack. These fires were extinguished by men inside and negligible damage resulted. A few window frames in the east and west walls and 2 or 3 desks in the first story of Building 122 were ignited by radiated heat and sparks from the west and northeast exposures. These fires were extinguished quickly and damage was negligible.

A. SUMMARY

1. The atomic bomb detonated at Hiroshima was an extremely effective and powerful blast weapon. Blast effect was essentially similar to that produced by a large charge of high explosive except that it was on a much larger scale; thus, damage was characterized by distortion or crushing of entire buildings rather than collapse of a single truss or rupture of a single wall.

2. Usual blast phenomena such as shielding, reflection, and diffraction were observed. The positive phase of the blast of the atomic bomb is believed to have been of comparatively longer duration that that of high explosives.

3. The primary cause of damage to buildings was blast. In many instances the fire which swept the central portion of the city increased distortion of the building frames, and consumed the combustible contents and interior trim and finish of most of the fire-resistive buildings located within the burned-over area. Blast damage to wood-frame buildings extended well beyond the limits of the burned-over area and it is probable that all wood-frame structures within the burned-over area suffered structural damage initially by blast.

4. The mean areas of effectiveness (MAE) of the atomic bomb for structural damage about ground zero (GZ) and the radii of the MAE's for the several classes of buildings present were computed to be as follows:

	MAE's in square miles	Radii of MAE's in feet
Multistory, earthquake-resistant	0.03	500
Multistory, steel- and reinforced-concrete frame (including both earthquake- and non-earthquake-resistant construction)	.05	700
1-story, light, steel-frame	3.4	5,500
Multistory, load-bearing, brick-wall	3.6	5,700
1-story, load-bearing, brick-wall	6.0	7,300
Wood-frame industrial-commercial (dimension-timber construction)	8.5	8,700
Wood-frame domestic buildings (wood-pole construction)	9.5	9,200
Residential construction	6.0	7,300

Of the values listed above, those for wood-frame and residential construction are peculiar to Japan and are not applicable to any other locality.

5. MAE's for similar, high, air-burst atomic bombs against Occidental construction were estimated to be approximately:

	Square miles
Multistory, steel- and reinforced-concrete	0.06
Very light, steel-frame one-story, low-cost industrial and storage	3.4
Multistory, load-bearing, brick wall	3.6
One-story, load-bearing, brick wall	6.0

MAE values against other types of Occidental construction, including moderate to heavy, steel-frame, industrial construction, could not be estimated because buildings of comparable construction were not present in Hiroshima.

6. Fire was the principal cause of damage to contents. In multistory frame construction fire caused the major part of all contents' damage, suffering only slight to moderate initial damage from blast and debris. Contents in light, steel-frame buildings suffered moderate initial damage from blast and, subsequently, in the burned-over area, almost total damage by fire. Outside the burned-over area there was some exposure damage. Blast and debris were the major causes of damage to contents of brick buildings, additional damage resulting from fire and exposure. Throughout the burned-over area practically all contents of wood-frame buildings were destroyed by fire. Beyond the limits of the fire there was slight to moderate damage to contents from blast, debris, and exposure.

7. Except for multistory, steel- and concrete-frame buildings, contents and structural damage to buildings were generally of similar extent at corresponding distances from air zero (AZ).

8. Had the bomb detonated at a somewhat lower altitude, damage to multistory, steel- and reinforced-concrete frame buildings which were clustered relatively near GZ probably would have been greater. The effect of such an explosion upon the extent of damage to other classes of buildings is uncertain, but probably would not have been great.

9. Comparison of the atomic bomb with high-explosive weapons results, at best, in very rough approximations because of the assumptions necessary. Based upon damage to load-bearing, brick-wall structures, an equivalent bare charge of approximately 4,400 tons of TNT was estimated.

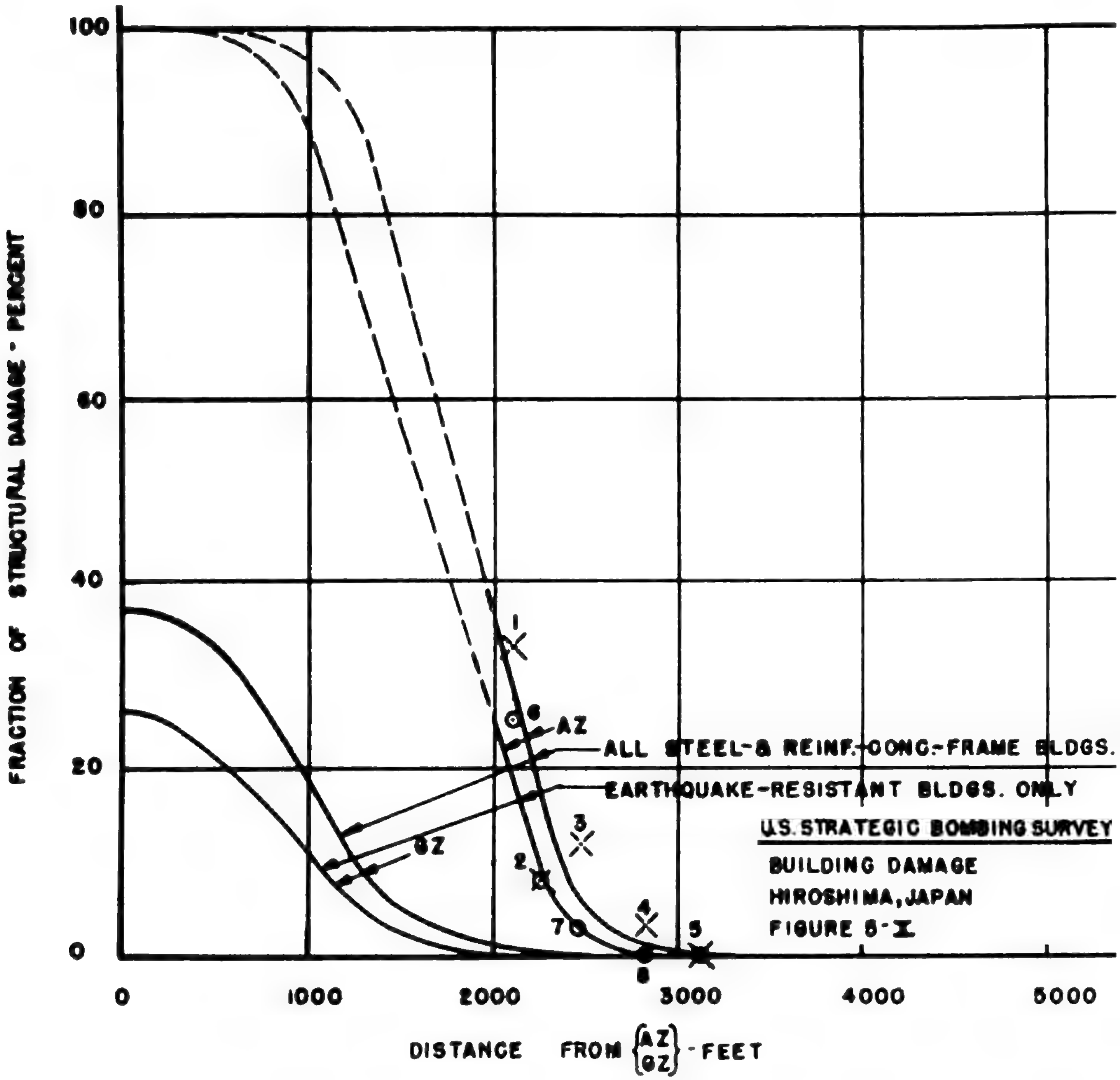
10. Because of the large area through which damage extended, particularly to load-bearing brick construction which constitutes a large proportion of the residential and older industrial sections of occidental cities, the air-burst atomic

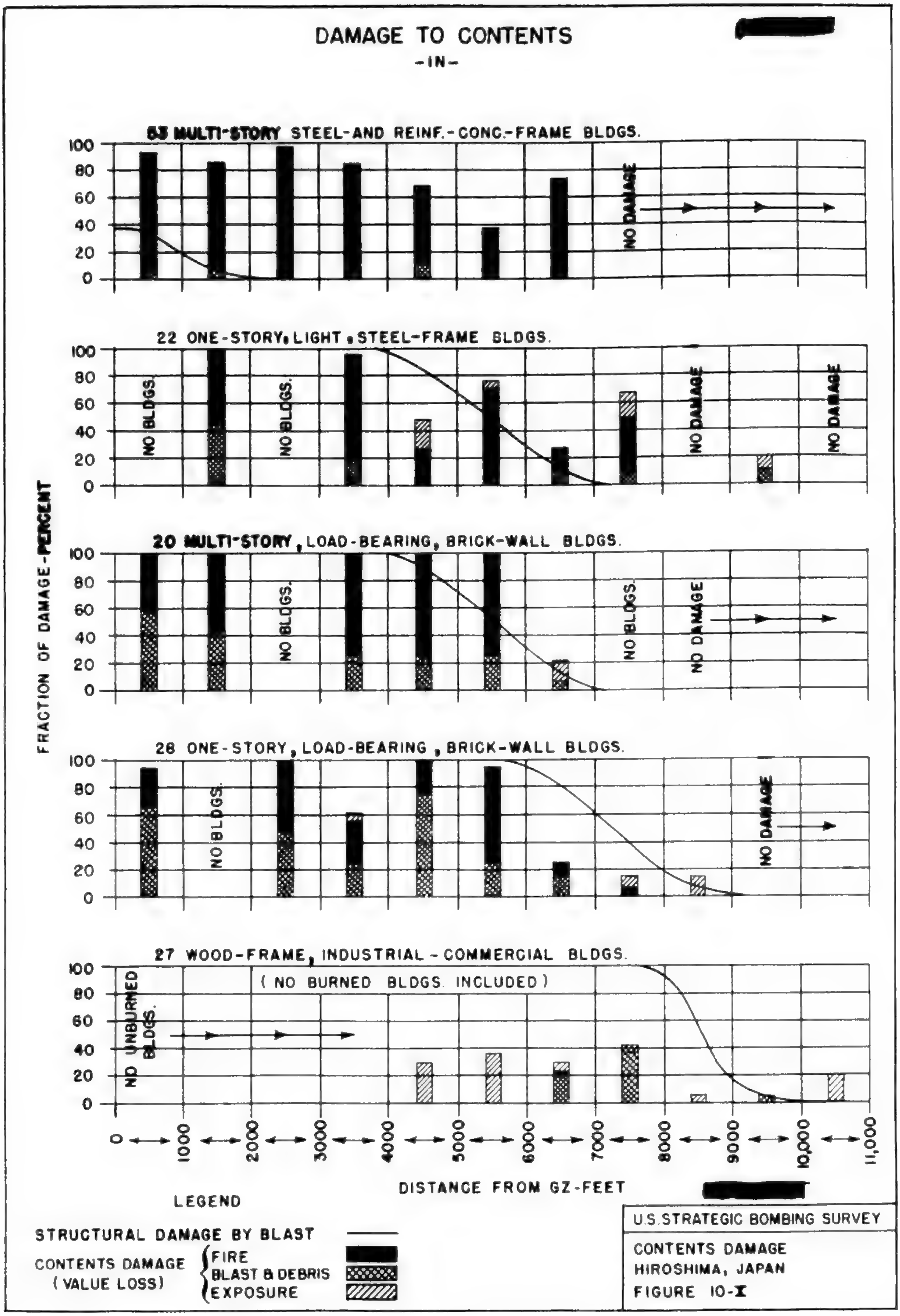
Table 1.—*Building data, steel- and reinforced-concrete-frame*

[Areas in thousands of square feet]

Building	Grid	Occupancy	Type	Plan area	Stories	Building HE-V	Building fire-V	Distance AZ-(feet)	Total floor area	Building damage—floor area: Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Superficial damage: Blast	Superficial damage: Fire	Internal fire	Content damage: Percent	Content damage: Cause
1	4H	Office	E1	1.7	2	V-1	R	2,100	4.2	1.8					3.5	90	Fire.
2	4H	do	E1	8.3	2/3	V-1	R	2,200	27.3	1.1					24.3	90	Do.
6	5H	do	E1	5.1	3	V-1	R	2,100	16.6						15.3	95	Do.
8	5H	Bank	E1	5.3	1/3	V-1	R	2,100	9.0	5.3					9.0	100	Do.
9	5H	Office	E1	2.1	2/3	V-1	R	2,100	4.9	1.0					4.2	90	Do.
11	5H	do	E1	4.6	3	V-1	R	2,100	9.8	2.1					9.8	100	Do.
18	5H	Bank	E1	10.1	5/2	V-1	R	2,200	45.0	1.9					46.4	100	Do.
19	5H	do	E1	8.8	4	V-1	R	2,200	29.9	2.7					25.2	90	Do.
20	5H	Office	E1	1.5	3	V-1	R	2,200	4.5	.1					4.5	100	Do.
21	5H	Bank	E1	5.5	1/2	V-1	R	2,300	7.3	5.7					7.3	100	Mixed.
22	5H	Office	E1	4.7	4	V-1	R	2,300	20.4	1.6			2.1		20.4	100	Fire.
23	5H	do	E1	5.4	7	V-1	R	2,300	43.3	4.6					39.0	90	Do.
24	5H	Bank	E1	10.6	3	V-1	R	2,400	32.8						5.2	30	Mixed.
26	5H	Office	E1	9.2	5	V-1	R	3,000	52.0				.2		46.5	90	Fire.
27	5H	Library	E1	5.3	2/4	V-1	R	3,100	13.4		0.8				13.4	100	Do.
28	6H	Office	E1	21.3	4	V-1	R	3,800	98.4						84.9	95	Do.
31	6H	Hospital	E1	27.5	3/4	V-1	R	5,300	88.6						0	25	Debris.
32A	6H	Classrooms	E1	1.4	2	V-1	R	5,100	2.8						2.8	100	Fire.
32B	6H	Library	E1	1.9	2	V-1	R	5,200	3.7						3.7	100	Do.
32D	6H	Classroom laboratory	E1	34.4	3	V-1	R	5,000	103.3						103.3	100	Do.
32E	6H	Classrooms	E1	13.2	3	V-1	R	4,700	39.5						39.5	100	Do.
33	6H	Office	E1	11.2	4	V-1	R	5,600	62.6						0	15	Blast-debris.
38	5H	do	E1	2.6	3	V-1	R	2,900	10.4						10.4	100	Fire.
39	5I	do	E1	15.5	3/4	V-1	N/R	3,200	32.0				4.4		32.0	100	Do.
40	5H	Department store	E1	9.9	7	V-1	R	3,200	78.9						78.9	100	Do.
41	5H	Classrooms	E1	7.2	3	V-1	R	2,600	26.4						25.1	95	Do.
43	5H	Telephone exchange	E1	16.3	2/3	V-1	R	2,800	36.1						36.1	100	Do.
44	5H	Department store	E1	2.6	1/3	V-1	R	2,700	4.3	1.7					4.3	100	Do.
47	5H	Beer hall	E1	4.8	3	V-1	R	3,100	15.3						13.2	80	Do.
49	5I	Office	E1	2.1	7	V-1	R	3,600	14.7						14.7	100	Do.
50	5I	Newspaper	E1	10.3	2/3	V-1	R	3,600	24.5						24.5	100	Do.
51	5I	Bank	E1	9.0	1/3	V-1	R	3,700	26.7						19.2	80	Do.
59	5I	Office	E1	4.8	2/3	V-1	R	4,500	16.2						0	10	Blast.
61	5I	Radio station	E1	4.2	2	V-1	R	4,000	8.3						8.3	100	Fire.
62	5I	Residence	E1	1.1	2	V-1	R	4,100	2.2						2.2	100	Do.
64	3I	Hospital	E1	6.8	2	V-1	R	5,300	15.9						5.3	40	Mixed.
65	3I	Office	E1	20.8	4	V-1	R	5,300	83.4						50.0	70	Do.
74	3H	Electrical laboratory	E1	6.6	2	V-1	R	6,300	13.2						10.6	80	Fire.
79	3G	Warehouse	E1	7.7	2	V-1	R	6,100	14.4		9.9			2.3	14.4	100	Do.
85	4G	Telephone exchange	E1	4.8	3	V-1	R	3,800	14.2						1.1	50	Mixed.
86	5G	Classrooms	E1	3.8	3	V-1	R	2,800	11.0						0	30	Debris.
95	4G	do	E1	12.4	3	V-1	R	2,300	49.5	0.5			3.0		49.5	100	Fire.
96	5G	Clothing store	E1	4.1	3	V-1	R	2,000	12.4	3.9					9.3	75	Do.
116A	7J	Warehouse	E1	23.7	3	V-1	R	8,800	71.1						0	0	
116B	7J	do	E1	23.7	3	V-1	R	8,900	71.1						0	0	
116C	7J	do	E1	23.7	3	V-1	R	9,000	71.1						0	0	
116F	7J	do	E1	23.7	3	V-1	R	9,200	71.1						0	0	
122	5J	Bank	E1	2.6	2	V-1	R	6,700	5.1						0	0	
12	5H	Office	E2	4.5	3	V-3	R	2,100	15.8	10.8			0.7		15.8	100	Mixed.
16	5H	Electric substation	E2	1.6	3	V-3	N	3,100	4.1				.4.1		2.5	50	Do.
25	5H	Art museum	E2	3.3	2	V-3	R	2,400	5.4	0.3			2.1		5.4	100	Fire.
46	5H	Jewelry store	E2	.9	2	V-3	N/C	2,800	1.9	1.9					1.9	100	Mixed.
48	5H	Hospital	E2	1.5	2	V-3	R	3,300	2.9						2.9	100	Fire.
98	5G	Warehouse	E2	1.5	2	V-3	R	2,500	2.9	2.9					2.9	100	Mixed.
100	5G	Office	E2	1.5	2	V-3	R	2,100	3.0				.1		3.0	100	Fire.
101	5G	Warehouse	E2	2.2	2	V-3	R	2,600	4.3	4.3					4.3	100	Debris.
121	4J	Railroad station	E1	9.0	1/2	V-3	N/C	6,600	14.0	4.9	4.9				14.0	100	Fire.
67	3H	Munitions storage	A2.4	1.7	1	V-4	R	5,000	1.7	1.7					0	10	Exposure.
76	3G	Warehouse	A2.4	15.9	1	V-4	R	6,200	15.9	1.9					15.9	100	Fire.
113C	7I	Cigarette manufacturing.	A1.2	54.6	1	V-4	R	7,700	54.6						0	0	
113D	7I	do	A1.2	54.9	1	V-4	R	7,800	54.9						0	0	
126A	5K	Railroad roundhouse	A2.4	21.1	1	V-4	R	8,900	21.1						0	0	
126B	5K	do	A1.2	11.6	1	V-4	R	9,000	11.6						0	0	

STRUCTURAL DAMAGE BY BLAST
TO
MULTI-STORY, STEEL- AND REINFORCED-CONCRETE-FRAME BUILDINGS
(BASED ON TOTAL FLOOR AREA)
MAE FOR ALL STEEL-& REINF.-CONC.-FRAME BLDGS = 0.05 SQ MI
MAE FOR EARTHQUAKE-RESISTANT BLDGS ONLY = 0.03 SQ MI





U.S. STRATEGIC BOMBING SURVEY

CONTENTS DAMAGE
HIROSHIMA, JAPAN
FIGURE 10-I

TABLE 7.—*Combustible building data (fire)*

Building Number	Coordinators	Distance from AZ (feet)	Distance from GZ (feet)	Occupancy	Fire shutters on wall openings	Unprotected wall openings exposed to AZ at zero hour	Distance from unprotected wall openings to nearest burned building (feet)	Probable cause of initial ignition	Number of stories	Stories burned (after blast damage)	Areas in thousands square feet		Percent floor area burned
											Total floor area	Floor area burned	
3	4H	2,200	900	Electric substation	No	Yes	40	Secondary	B-1	B-1	3.8	3.8	100
4	5H	2,000	400	Mercantile	No	Yes	15		3	1-3	30.0	30.0	100
5	5H	2,000	100	Hospital	No	Probably no	15		1	1	2.3	2.3	100
13	5H	2,300	1,300	Office	Yes	Yes	10		3	1-3	5.6	5.6	100
14	5H	2,400	1,400	Bank	No	Yes	10		2	1-2	3.1	3.1	100
15	5H	3,000	2,200	Electric repair	No	Yes	0		1	1	6.9	6.9	100
17	5H	2,200	900	Office	No	Yes	0		2	1-2	4.0	4.0	100
29	6H	4,600	4,200	Soy sauce warehouse	No	Yes	5	Fire spread	2	1-2	1.4	1.2	100
30	7H	5,800	5,500	Gymnasium	No	Yes	5	do	1	1	5.8	5.8	100
32C	6H	5,300	4,900	Library	Yes	No	0	do	3	1-3	5.9	5.9	100
34	6H	5,500	5,200	Art museum	Yes	No	0	do	2	1-2	2.4	2.4	100
37	6H	4,600	4,200	Public baths	No	Yes	0	Secondary	1	1	1.2	1.2	100
42	5H	2,600	1,600	Public auditorium	No	Yes	10		2	1-2	11.9	11.9	100
53	5I	3,800	3,200	Warehouse	No	Probably no	10		1	1	.9	.9	100
54	5I	3,700	3,100	Match manufacturing	No	Yes	10		1	1	2.7	2.7	100
55	5H	3,700	3,100	Electrical warehouse	Yes	Yes	5		2	1-2	9.9	9.9	100
57	5I	4,700	4,300	Gymnasium	No	Yes	20	Fire spread	1	1	6.2	6.2	100
60	5I	3,600	3,000	Church	No	Yes	5	do	1	1	3.1	3.1	100
66A	4I	4,500	4,000	Army stores	Yes	Probably no	20	do	2	1-2	19.1	19.1	100
66B	4I	4,400	3,900	do	Yes	Probably no	25	do	2	1-2	19.1	19.1	100
66C	4I	4,600	4,200	do	Yes	Probably no	30	do	2	1-2	19.1	19.1	100
66D	4I	4,800	4,400	do	Yes	Probably no	50	do	2	1-2	19.1	19.1	100
68A	4H	3,200	2,500	do	Yes	Probably yes	60		1	1	14.4	14.4	100
68B	4H	3,300	2,600	do	Yes	Probably yes	60		1	1	14.4	14.4	100
68C	4H	3,500	2,800	Army stores	Yes	Probably yes	60		1	1	14.4	14.4	100
69	4H	3,000	2,300	do	Yes	Probably yes	40		1	1	14.4	14.4	100
70	2H	7,500	7,200	Auditorium	No	Yes	15	Fire spread	1-Bal.	1-Bal.	6.4	6.4	100
71	2H	7,800	7,600	Gymnasium	No	Yes	10	do	1	1	6.4	6.4	100
72	3H	6,500	6,200	Aluminum foundry	No	Yes	15	Secondary	1	20% 1	13.0	2.6	20
77	3G	6,700	6,400	Gymnasium	No	Yes	20	Fire spread	1	1	5.6	5.6	100
80	3G	6,200	5,900	Iron foundry	No	Yes	100	No fire	1	None	6.5	0	0
82	3G	4,400	3,900	Light machine shop	No	Yes	0	do	1	None	9.5	0	0
83	4G	3,900	3,300	do	No	Yes	0		1	1	3.6	3.6	100
84	4G	3,900	3,300	do	No	Yes	0		1	1	7.0	7.0	100
92	5G	2,400	1,300	Bank	Yes	Yes	0		2	1-2	2.9	2.9	100
94	5G	2,300	1,100	Light manufacturing	No	Yes	15		1-Bal	1-Bal.	4.4	4.4	100
97	7G	6,300	6,000	Light machine shop	No	Yes	50	No fire	1	None	3.2	0	0
98A	7G	6,700	6,400	Paper machinery	No	Yes	0	Fire spread	2	2% 2d only	7.5	.1	1
99	7G	6,800	6,500	Office storage	No	Yes	40	No fire	1	None	5.8	0	0
102A	4F	5,300	4,900	Machine shop	No	Yes	25	do	1	None	5.3	0	0
102B	4F	5,300	4,900	do	No	Yes	25	do	1	None	5.3	0	0
102C	4F	5,300	4,900	do	No	Yes	25	do	1	None	5.9	0	0
104	3G	5,400	5,000	Gymnasium	No	Yes	35	do	1	None	13.0	0	0
106	4F	4,400	3,900	Light machine shop	No	Yes	15	do	1	1	3.3	0	0
107	4F	4,200	3,700	Gymnasium	No	Yes	25	Fire spread	1	None	2.3	0	0
108	5F	6,200	5,900	Auditorium	No	Yes	25	No fire	1-Bal	1	4.8	4.8	100
110	5J	6,200	5,900	Bank	Yes	No	0	Fire spread	2	None	8.4	0	0
111	5J	6,300	6,000	Grain warehouses	No	Probably no	75	do	1	1-2	2.6	2.6	100
112C	7I	6,900	6,600	Miscellenaous storage	No	Yes	80	No fire	1	1	30.6	30.6	100
112D	7I	6,900	6,600	Light machine shop	No	No	50	do	1	None	.9	0	0
113G	7I	7,400	7,100	Miscellaneous storage	No	Yes	20	do	1	None	.8	0	0
120	4J	6,000	5,700	Printing shop	No	Yes	6	Fire spread	1	None	4.2	4.2	0
128	6H	6,000	5,700	Gymnasium	No	Yes	25	do	1	1	4.3	4.3	100
131B	7H	8,000	7,700	Boiler house	No	Yes	50	do	1	1	5.8	5.8	100
										1	5.0	5.0	100

PHOTO 3-XA. Building 2. Looking NE. Note lightning rods on roof were not damaged by blast. Building gutted by fire.

Building No.: 2. Coordinates: 4H. Distance from (GZ): 800, (AZ): 2.100.

NAME: Hiroshima Chamber of Commerce.

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: 3 and basement. JTG class: E1.

Roof: 5-inch reinforced-concrete slab and beam.

Partitions: Reinforced concrete, major-tile, secondary.

Walls: Reinforced concrete.

Floors: Wood over reinforced-concrete beam and slab.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 5. Coordinates: 5H. Distance from (GZ): 100, (AZ): 2,000.

NAME: Shima Surgical Hospital.

CONSTRUCTION AND DESIGN

Type: Bearing wall.

Number of stories: 1. JTG class: A 2-3.

Roof: Tile over wood on wood truss.

Partitions: Plaster on wood lath and studs.

Walls: Brick-bearing, 18 inches.

Floors: Wood on wood beams.

Framing: Wall bearing—roof only wood.

Window and door frames: Steel. Ceilings: Unknown.

Condition, workmanship and materials: Excellent.

Compare with usual United States buildings: Greater strength than comparable United States type and occupancy.

OCCUPANCY: Doctor's office and private hospital.

CONTENTS: Office and medical equipment.

DAMAGE to building: Complete destruction. Entire building including walls leveled to the top of the foundation.

Cause: Blast.

To contents: Complete destruction.

Cause: Debris (primary). Combustibles burned.

TOTAL FLOOR AREA (square feet): 2,340. Structural damage: 2,340. Superficial damage: —.

FRACTION OF DAMAGE: Building structural: 100 percent. Superficial: —. Contents: 100 percent.

REMARKS: Of buildings studied this is the nearest to GZ. Destruction was so complete as to preclude obtaining details on roof trusses.

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 5. Fire classification: C.

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:				
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	25′	No	C	Yes	
E	15′	No	C	Yes	
S	20′	No	C	Yes	
W	30′	No	C	Yes	

PROBABLE CAUSE OF FIRE: Not determined.

VERTICAL FIRE SPREAD:

EXTENT OF FIRE: Total floor area: 2,300 square feet. Floor area burned: 2,300 square feet. 100 percent (after blast damage).

REMARKS:

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 6. Coordinates: 5H. Distance from (GZ): 600, (AZ): 2,100.

NAME: Chiyoda Life Insurance Co., Chugoku branch.

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: Three and basement. JTG class: E1.

Roof: Reinforced-concrete beam and slab-tile covered.

Partitions: Reinforced-concrete, major—metal lath and plaster, minor.

Walls: Reinforced-concrete panels, 10 inches. Reinforced-concrete granite facing.

Floors: Reinforced-concrete beam and slab.

Framing: Reinforced-concrete beam and slab.

Window and door frames: Steel. Ceilings: Wood lath and plaster third floor only.

Condition, workmanship, and materials: Excellent.

Compare with usual United States buildings: Extremely heavy construction, especially beams and columns.

OCCUPANCY: Life insurance office.

CONTENTS: Office equipment.

DAMAGE to building: Minor cracking in roof slab and beams, sash trim windows, etc., destroyed by internal fire—minor damage only.

Cause: Fire.

To contents: Completely destroyed.

Cause: Fire.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 6. Fire classification: R.

WALL OPENINGS: Shutters: Steel rollers.

Shut: Yes.

Effect of blast: Blown in.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	None		
Elevators:	Yes	Metal	No	Blown in.

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	10′	No	C	Yes	
E	15′	No	C	Yes	
S	20′	No	C	Yes	
W	30′	No	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposures.

VERTICAL FIRE SPREAD: Probably up stairs and elevator.

EXTENT OF FIRE: Total floor area: 16,600 square feet. Floor area burned: 15,300 square feet. 92 percent (after blast damage).

REMARKS: Fire in entire building except about 30 percent of basement.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 10 **Coordinates:** 5H. **Distance from (GZ):** 600, **(AZ):** 2,100.

NAME: Nippon Life Insurance Co., Hiroshima branch.

CONSTRUCTION AND DESIGN

Type: Load-bearing brick wall.

Number of stories: See drawing. **JTG class:** F2.

Roof: Reinforced-concrete slab 6 inch (½-inch bars 6-inch oc by 12 inch oc).

Partitions: Major, 13-inch brick, minor, plaster and wood stud.

Walls: Brick 18- and 4-inch stone trim on front.

Floors: Concrete on earth-wood beams and flooring second floor.

Framing: Reinforced concrete and wood framed second floor.

Window and door frames: Wood. **Ceilings:** Unknown.

Condition, workmanship, and materials: Fair concrete not of good quality.

Compare with usual United States buildings: Considerably stronger.

OCCUPANCY: Life insurance company.

CONTENTS: Insurance and office equipment.

DAMAGE to building: Roof partially collapsed—remainder depressed and ruptured. Walls cracked and buckled partially collapsed.

Cause: Blast.

To contents: Completely destroyed.

Cause: Debris and fire (about equally).

TOTAL FLOOR AREA: (square feet): 2,500. Structural damage: 2,500. Superficial damage:

FRACTION OF DAMAGE: Building structural: 100 percent. Superficial: —. Contents: 100 percent.

REMARKS: Entire building so out of plumb and cracked as to be in a virtual state of collapse.

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No: 10. **Fire classification:** R.

WALL OPENINGS: Shutters: Steel rollers.

Shut: Part.

Effect of blast: Blown in.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	Metal	No	Blown in.
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	10'	No	C	Yes	
E	20'	No	C	Yes	
S	30'	No	R	Yes	Building 11 (10' wall between).
W	30'	No	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposure.

VERTICAL FIRE SPREAD: Possibly.

EXTENT OF FIRE: Total floor area: 2,500. Square feet floor area burned: 2,500. Square feet: 100 percent (after blast damage).

REMARKS:

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 18. Coordinates: 5H. Distance from (GZ): 1,000, (AZ): 2,200.

NAME: Geibi Bank Co., Hiroshima Branch.

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: 5 and ½ basement. JTG class: E1.

Roof: Reinforced-concrete slab (metal pan).

Partitions: Reinforced-concrete (5-inch). Wood lath and plaster in rear addition.

Walls: Reinforced concrete (10-inch).

Floors: Reinforced-concrete slabs (metal pan construction).

Framing: Reinforced concrete, heavy haunches.

Window and door frames: Metal. Ceilings: Plaster on concrete.

Condition, workmanship, and materials: Good.

Compare with usual United States buildings: Considerably heavier in structural framing.

OCCUPANCY: Bank and office.

CONTENTS: Bank equipment and furnishings.

DAMAGE to building: Light steel-framed roof over rear addition destroyed by blast. Portion of roof of main building depressed, beams cracked and spalled at haunches and center of span-steel elongated. Minor damage throughout.

Cause: Blast.

To contents: Destroyed.

Cause: Fire.

TOTAL FLOOR AREA (square feet): 46,400. Structural damage: 3,260. Superficial damage:

FRACTION OF DAMAGE: Building structural 7 percent. Superficial: —. Contents: 100 percent.

REMARKS: 1,400 square feet of structural damage shown above was in inferior construction.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 18. Fire classification: R.

WALL OPENINGS: Shutters: Steel rollers in west section and in north wall only of east section.

Shut: Yes.

Effect of blast: Most blown in.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	Steel rollers	No	None—doors open
Elevators:	Yes	Steel rollers	No	None—doors open

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	10′	No	C	Yes	
E	25′	No	C	Yes	
S	20′	No	R	Yes	Building 19 (14-foot wall between).
S	40′	No	C	Yes	14-foot concrete wall between.
W	125′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposure.

VERTICAL FIRE SPREAD:

EXTENT OF FIRE: Total floor area: 46,600 square feet. Floor area burned: 46,400 square feet; 100 percent (after blast damage).

REMARKS: Fires in exposures soon after bomb. This building well afire at 1000 hours.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 23. Coordinates: 5H. Distance from (GZ): 1,200; (AZ); 2,300.
NAME: Fukoku Building.
CONSTRUCTION AND DESIGN
Type: Steel core reinforced-concrete frame.
Number of stories: 7 and basement. JTG class: E1.
Roof: Reinforced-concrete beam and slab (steel core).
Partitions: Reinforced concrete.
Walls: Reinforced concrete, stone trim.
Floors: Reinforced concrete, wood finish.
Framing: Reinforced concrete.
Window and door frames: Metal. Ceilings: Metal lath and plaster.
Condition, workmanship, and materials:
Compare with usual United States buildings:
OCCUPANCY: First story, commercial. Remainder, office space.
CONTENTS: Office equipment and furnishings, communication equipment second and third floor.
DAMAGE to building: Long-span trusses supporting roof ruptured and roof depressed. Three panels of first floor slab depressed by blast. Minor damage from fire throughout building.
Cause: Blast.
To contents: Almost complete destruction except in basement.
Cause: Fire (primary); some debris damage.
TOTAL FLOOR AREA (square feet): 43,300. Structural damage: 4,600. Superficial damage:
FRACTION OF DAMAGE: Building structural: 11 percent. Superficial: —. Contents: 90 percent.
REMARKS:

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 23. Fire classification: N/R (unprotected steel in roof).
WALL OPENINGS: Shutters: No (wired glass in all windows).
Shut:
Effect of blast: All broken.
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	Metal and W. G.	No	Part blown off.
Elevators:	Yes	Metal and W. G.	No	Part blown off

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	10'	No	R	Yes	Building 22.
E	100'	Yes	C	Yes	
S	25'	No	C	Yes	
W	125'	Yes	C	Yes	

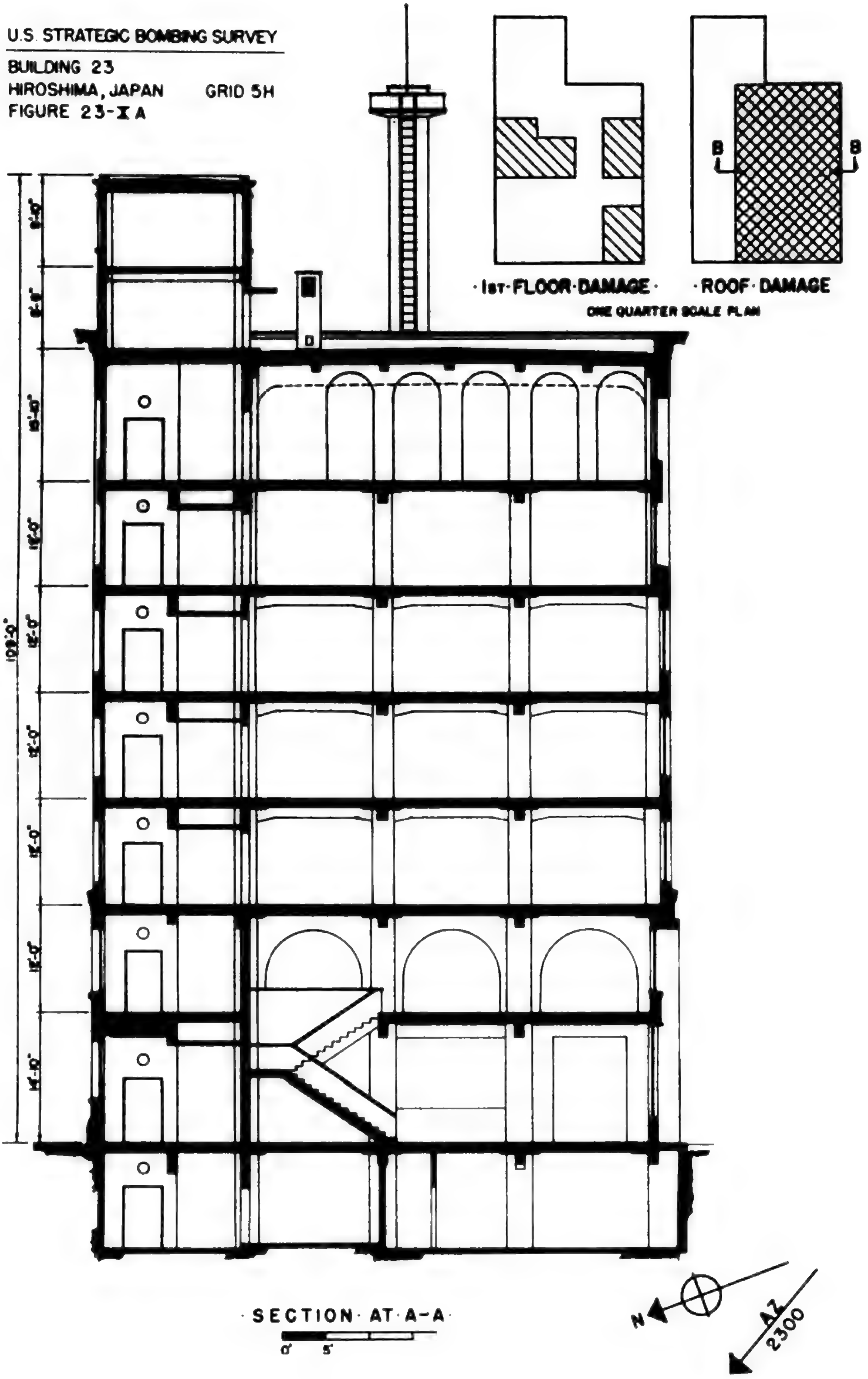
PROBABLE CAUSE OF FIRE: Not determined.
VERTICAL FIRE SPREAD: Probably up stairs, elevator and pipe shaft.
EXTENT OF FIRE: Total floor area: 43,300 square feet. Floor area burned: 39,000 square feet; 90 percent (after blast damage).
REMARKS: Fire throughout building except in basement.

U.S. STRATEGIC BOMBING SURVEY

BUILDING 23

HIROSHIMA, JAPAN GRID 5H

FIGURE 23-X A



U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 24. Coordinates: 5H. Distance from (GZ): 1,300, (AZ): 2,400.
NAME: Bank of Japan, Hiroshima branch.
CONSTRUCTION AND DESIGN
Type: Reinforced-concrete frame (steel core).
Number of Stories: 3 and basement. JTG class: E1.
Roof: Reinforced-concrete beam and slab.
Partitions: Reinforced concrete and wood lath.
Walls: Reinforced concrete (12-inch) and stone (6-inch).
Floors: Reinforced concrete.
Framing: Reinforced concrete.
Window and door frames: Metal (exterior) wood (interior). Ceilings: Plaster on concrete.
Condition, workmanship, and materials: Excellent.
Compare with usual United States buildings: Much stronger—steel core construction.
OCCUPANCY: Bank.
CONTENTS: Bank and office equipment furnishings.
DAMAGE to building: Only minor damage—top story burned out, partitions, sash, trim blown out in two lower stories.
Cause: Fire.
To Contents: Destroyed in third story—moderate debris and blast damage in first and second stories, none in basement.
Cause: Fire and debris (about equally).
TOTAL FLOOR AREA (square feet): 32,800. Structural damage: —. Superficial damage:
FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents: 30 percent.
REMARKS: Glass removed from skylight (20 by 20 feet) and light steel-frame structure and roof covered with 12 to 18 inches of sand and cinders.

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 24. Fire classification: R.
WALL OPENINGS: Shutters: Steel rollers.
Shut: Part.
Effect of blast: Blown in.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	Steel rollers	No	None—doors open.
Elevators:	Yes	Metal and W. G.	No	Bent.

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	25′	No	C	Yes	14-foot concrete wall between.
E	25′	No	R	Yes	Building 25 (14-foot wall between).
S	—	No	—	—	No exposure.
W	125′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposures.
VERTICAL FIRE SPREAD: No.
EXTENT OF FIRE: Total floor area: 32,800 square feet. Floor area burned: 5,200 square feet; 16 percent (after blast damage).

REMARKS: Fire only in room at southwest corner of second story and in entire third story. No fire in building right after bomb, but afire at 1000 hours. Fire in room in second story extinguished with water buckets.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 26. Coordinates: 5H. Distance from (GZ): 2,300, (AZ): 3,000.

NAME: Chugoku Electric Co.

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: 5 and basement and penthouse JTG class: E1.

Roof: Reinforced-concrete beam and slab.

Partitions: Reinforced concrete (6-inch).

Walls: Reinforced concrete (12-inch).

Floors: Reinforced-concrete slab, parquet wood surface 3, 4, 5, and 6 floors.

Framing: Reinforced-concrete beam and slab.

Window and door frames: Metal. Ceilings:

Condition, workmanship, and materials; Excellent.

Compare with usual United States buildings: Considerably stronger.

OCCUPANCY: Office.

CONTENTS: Office equipment and furnishings.

DAMAGE to building: One roof slab and girder cracked by blast. Minor damage throughout from blast and fire.

Cause: Blast:

To contents: Severe damage, except in west section of basement and a portion of east section of basement.

Cause: Fire 75 percent. Blast and debris 15 percent.

TOTAL FLOOR AREA (square feet): 52,000. Structural damage: —. Superficial damage: 220.

FRACTION OF DAMAGE: Building structural: —. Superficial: 0.25 percent. Contents: 90 percent.

REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 26. Fire classification: R.

WALL OPENINGS: Shutters: Steel rollers in north wall of west section only.

Shut: Part.

Effect of blast: Most blown in.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	No			
Elevators:	Yes	No		

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	60′	Yes	C	Yes	
E	35′	No	C	Yes	
SE	10′	No	C	Yes	
S	50′	No	R	Yes	Building 27.
W	150′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Direct heat radiation from bomb.

VERTICAL FIRE SPREAD: Possibly upstairs and pipe shaft.

EXTENT OF FIRE: Total floor area: 52,000 square feet. Floor area burned: 46,500 square feet; 88 percent (after blast damage).

REMARKS: Fire throughout building except in 60 percent of basement (no fire in basement of west section and about 25 percent of east section). Man who was in third story stated that he saw cotton blackout curtains in west wall and thin paper on desks catch fire from flash of bomb. Fire was reported to have been in all stories 5 minutes after bomb.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 28. Coordinates: 6H. Distance from (GZ): 3,300, (AZ): 3,800.
NAME: Hiroshima City Hall.
CONSTRUCTION AND DESIGN
Type: Reinforced concrete, stucco finish.
Number of stories: Four and basement. JTG class: E1.
Roof: Reinforced concrete, tile finish.
Partitions: Reinforced concrete (5-inch) and tile, wood wainscoats in stair halls.
Walls: Reinforced concrete (10-inch).
Floors: Reinforced concrete, cement finish.
Framing: Reinforced concrete.
Window and door frames: Metal. Ceilings:
Condition, workmanship, and materials: Excellent.
Compare with usual United States buildings: Considerably stronger.
OCCUPANCY: Office.
CONTENTS: Furnishings and equipment for office and city administration.
DAMAGE to building: Minor damage only—sash blown out, trim and finish destroyed by fire. Few tile partitions blown out.
Cause: Fire and blast.
To contents: Severely damaged.
Cause: Fire.
TOTAL FLOOR AREA (square feet): 93,400. Structural damage: —. Superficial damage:
FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents: 75–100 percent.
REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No. 28. Fire classification: R.
WALL OPENINGS: Shutters: None.
Shut:
Effect of blast:
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	No			
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	—	No	—	—	No exposure.
E	50′	Partial 200′	C	Yes	All exposure burned.
SE	125′	Yes	C	Yes	
W	150′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposure.
VERTICAL FIRE SPREAD: Probably.
EXTENT OF FIRE: Total floor area: 93,400 square feet. Floor area burned: 84,900 square feet; 91 percent (after blast damage).
REMARKS: Fire in entire building except of 20 percent of basement and first story at east end of east section (transverse partitions were noncombustible without openings and there were no combustible construction materials and contents in the corridors at the north wall. Two men who were in building at time of bomb stated that fire spread in from south exposure by flying embers at 1000 hours. Fire started first in the third story. Lower stories may have been ignited later directly by exposure fires.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 33. **Coordinates:** 6H. **Distance from (GZ):** 5,300, **(AZ):** 5,600.
NAME: Hiroshima Postal Savings Bureau.
CONSTRUCTION AND DESIGN
Type: Reinforced-concrete frame.
Number of stories: 4 and basement. **JTG class:** E1.
Roof: Reinforced concrete, tile finish.
Partitions: Reinforced concrete.
Walls: Reinforced concrete, tile finish.
Floors: Reinforced concrete.
Framing: Reinforced concrete.
Window and door frames: Metal, wood (interior). **Ceilings:** Plaster on wood lath—top story. Plaster on concrete—others.
Condition, workmanship, and materials: Excellent.
Compare with usual United States buildings: Much stronger.
OCCUPANCY: Office.
CONTENTS: Office furnishings and equipment.
DAMAGE to building: Minor—glass blown out, some sash deformed. Hung ceiling in top story 75 percent collapsed.
Cause: Blast.
To contents: Slight damage to furnishings and other contents from blast and debris.
Cause: Blast and debris.
TOTAL FLOOR AREA (square feet): 62,600. Structural damage: —. Superficial damage:
FRACTION OF DAMAGE: Building structural: Superficial: —. Contents: 15 percent.
REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2
(Fire Supplement to Sheet No. 1)

Building No.: 33. **Fire classification:** R.
WALL OPENINGS: Shutters: Steel rollers in north and east walls only of northeast section.
Shut: Few only.
Effect of blast: Bent inward slightly.
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	Metal	No	Part blown off.
Elevators:	Yes	Metal	No	Blown off.

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
NW	150'	Yes	C	Yes	
E	90'	Yes	C	Yes	
S	150'	Yes	C	Yes	
W	150'	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from west exposure.
VERTICAL FIRE SPREAD: None.
EXTENT OF FIRE: Total floor area: 62,600 square feet. Floor area burned: 0 square feet; 0 percent (after blast damage).
REMARKS: Sparks from west exposure ignited cotton black-out curtains in west wall at 2000 hours and waste paper in fourth story of northwest section at 2100 hours. Fires were extinguished with water buckets by 20 fire guards who were stationed inside. Fire damage to contents was negligible. Paper records stored in wood and steel racks in northeast section of building were exposed to direct radiated heat from bomb but did not catch fire.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 40. Coordinates: 5H. Distance from (GZ): 2,500, (AZ): 3,200.

NAME: Fukuya Department Store.

CONSTRUCTION AND DESIGN:

Type: Reinforced-concrete frame.

Number of stories: 7 and basement and one-half of eighth. JTG class: E1.

Roof: Reinforced-concrete beam and slab (steel trusses over theater).

Partitions: Metal lath and plaster.

Walls: 8-inch reinforced concrete—large windows.

Floors: Wood over reinforced concrete.

Framing: Reinforced concrete (or protected steel).

Window and door frames: Steel. Ceilings: Plaster on concrete.

Condition, workmanship, and materials: Good.

Compare with usual United States buildings: Considerably stronger than comparable United States buildings.

OCCUPANCY: Department store.

CONTENTS: Merchandise on display for sale.

DAMAGE to building: Minor throughout—sash blown out; finish and trim, including floors, burned out. Steel trusses supporting roof over theatre show slight deformation.

Cause: Mixed.

To contents: Destroyed.

Cause: Fire.

TOTAL FLOOR AREA (square feet): 78,900. Structural damage: —. Superficial damage:

FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents: 90–100 percent.

REMARKS:

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 40. Fire classification: R (north roof on west section).

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	Metal	No	Blown in or bent.
Elevators:	Yes	Metal	No	Blown in or bent.

EXPOSURE:

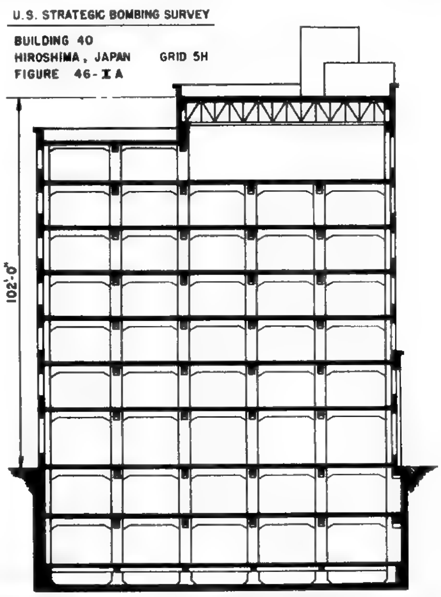
Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	50′	No	R	Yes	Building 39.
E	150′	Yes	C	Yes	
S	180′	Yes	C	Yes	
W	200′	Yes	R	Yes	Building 38.

PROBABLE CAUSE OF FIRE: Direct radiated head from bomb.

VERTICAL FIRE SPREAD: Probably.

EXTENT OF FIRE: Total floor area: 78,900 square feet. Floor area burned: 78,900 square feet; 100 percent (after blast damage).

REMARKS: Three persons who were questioned individually stated that this building was afire immediately or within 20 minutes after the bomb. One man who was in the building at the time stated that cotton blackout curtains in the west wall were smouldering immediately after the bomb. The entire building was afire at 1000 hours.



U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 47. Coordinates: 5H. Distance from (GZ): 2,300, (AZ): 3,100.

NAME: Hiroshima Kirin Beer Hall.

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: Three and basement. JTG class: E1.

Roof: Reinforced-concrete beam and slab.

Partitions: 5-inch reinforced concrete.

Walls: 8-inch reinforced concrete integral—large windows.

Floors: 5-inch reinforced-concrete beam and slab.

Framing: Reinforced concrete.

Window and door frames: Steel. Ceilings: Plaster on concrete.

Condition, workmanship, and materials: Good.

Compare with usual United States buildings. Considerably stronger than United States design.

OCCUPANCY: Beer hall.

CONTENTS: Bars, tables, etc.

DAMAGE to building: Minor—sash blown out, finish and trim partly destroyed by fire.

Cause: Mixed.

To contents: Moderate damage from both blast (throwing furnishings around) and fire.

Cause: Mixed.

TOTAL FLOOR AREA (square feet): 15,300. Structural damage: —. Superficial damage:

FRACTION OF DAMAGE: Building structural: —. Superficial —. Contents: 60–80 percent.

REMARKS: Building and contents contained so few combustibles that internal fire was not of great intensity.

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 47. Fire classification: R.

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	Metal and glass	No	Bent.
Elevators:	Yes	Metal and glass	No	Blown off.

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	—	Yes	—	—	No exposure.
E	20′	No	C	Yes	
S	—	Yes	—	—	No exposure.
W	65′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposures.

VERTICAL FIRE SPREAD: Possibly.

EXTENT OF FIRE: Total floor area: 15,300 square feet. Floor area burned: 13,200 square feet; 86 percent (after blast damage).

REMARKS: Man who worked in building but was not on premises at time of bomb stated that fire spread into building from east exposure about one hour after bomb. Entire building had fire in it except basement. Combustibility of contents was low and very little damage was done to building by fire.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 49. Coordinates: 5I. Distance from (GZ): 3,000, (AZ): 3,600.
Name: Chūgoku Newspaper.
CONSTRUCTION AND DESIGN
Type: Reinforced-concrete frame.
Number of Stories: 7 and penthouse. JTG class: E1.
Roof: Reinforced-concrete beam and slab.
Partitions: Reinforced concrete—lath and plaster.
Walls: 7-inch reinforced concrete—large windows.
Floors: 6-inch reinforced-concrete beam and slab—small part wood overlay.
Framing: Reinforced concrete (on steel frame).
Window and door frames: Steel. Ceilings: Plaster on concrete.
Condition, workmanship, and materials: Excellent.
Compare with usual United States buildings: Considerably heavier than United States.
OCCUPANCY: Newspaper office—used in conjunction with Building 50.
CONTENTS: Office equipment and supplies.
DAMAGE to building: Minor throughout; sash blown in, finish and trim destroyed by internal fire.
Cause: Fire.
To contents: Complete destruction.
Cause: Fire.
TOTAL FLOOR AREA (square feet): 14,700. Structural damage: —. Superficial damage:
FRACTION OF DAMAGE: Building structural: —. Superficial —. Contents: 100 percent.
REMARKS: Contents' damage based upon interrogation as all debris was removed.

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 49. Fire classification: R.
WALL OPENINGS: Shutters: Steel rollers at first to third stories of west wall only.
Shut: Part.
Effect of blast: Blown in.
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	No	No	
Elevators:	Yes	Metal		Part blown in.

EXPOSURE:

Location	Distance	Clearance	Firebreak Class	Fire Burned	Remarks
N	150'	Yes	C	Yes	
E and S	0'	No	R	Yes	Building 50 (unprotected openings).
S	185'	Yes	C	Yes	150 feet beyond Building 50.
W	90'	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Direct radiated heat from bomb.
VERTICAL FIRE SPREAD: Possibly.
EXTENT OF FIRE: Total floor area: 14,700 square feet. Floor area burned: 14,700 square feet; 100 percent (after blast damage).
REMARKS: Man who was in building at time of bomb stated fire broke out in third and fourth stories immediately after bomb flash. Head bookkeeper in bank in Building 51 stated that there was fire in third story of Building 49, 10 minutes after bomb flash.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 52. Coordinates: 5I. Distance from (GZ): 2,800, (AZ): 3,400.
NAME: Taiyo Theater.
CONSTRUCTION AND DESIGN
Type: Light steel frame.
Number of stories: —. JTG class:
Roof:
Partitions:
Walls:
Floors:
Framing:
Window and door frames: —. Ceilings:
Condition, workmanship, and materials:
Compare with usual United States buildings:
OCCUPANCY:
CONTENTS:
DAMAGE to building: Completely destroyed.
Cause: Mixed.
To contents: Completely destroyed.
Cause: Mixed.
TOTAL FLOOR AREA (square feet): Unknown. Structural damage: —. Superficial damage:
FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents: — percent.
REMARKS: Mixed construction. Damage too severe to permit analysis of cause of damage or design of structure.

Note.—Building damage based on total floor area. Contents damage if fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 52. Fire classification: C.
WALL OPENINGS: Shutters: None.
Shut:
Effect of blast:
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:				
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	0′	No	C	Yes	
E	90′	Yes	R	Yes	
S	0′	No	C	Yes	Buildings 49 and 50.
W	10′	No	C	Yes	

PROBABLE CAUSE OF FIRE: Not determined.
VERTICAL FIRE SPREAD:
EXTENT OF FIRE: Total floor area: — square feet. Floor area burned: — square feet; 100 percent (after blast damage).
REMARKS: This building was excluded from both blast and fire studies.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 59. Coordinates: 51. Distance from (GZ): 4,100, (AZ): 4,500.

NAME: Geibi Bank Co., Hiroshima Branch (in use at time of bomb as the Higashi Police Station).

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: See sketch. JTG class: E1.

Roof: Reinforced-concrete beam and slab.

Partitions: 7-inch reinforced concrete.

Walls: 8-inch reinforced concrete monolithic—medium window.

Floors: Reinforced-concrete beam and slab—parquet and tile.

Framing: Reinforced-concrete beam and slab.

Window and door frames: Steel. Ceilings: Sheet metal on wood framing.

Condition, workmanship and materials: Good.

Compare with usual United States buildings: Appreciably stronger than United States design.

OCCUPANCY: Police station (office).

CONTENTS: Office equipment.

DAMAGE to building: Minor damage only—sash blown out and hung ceilings partially stripped.

Cause: Blast.

To contents: Slight damage to contents from blast and debris.

Cause: Blast.

TOTAL FLOOR AREA (square feet): 16,200. Structural damage: —. Superficial damage:

FRACTION OF DAMAGE: Building. Structural: —. Superficial: Contents: 10 percent.

REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 59. Fire classification: R.

WALL OPENINGS: Shutters: Steel rollers in east wall and third story of south and west walls (wired glass in all windows).

Effect of blast: Blown in at west wall, bent at south wall.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	Metal	No	Bent slightly.
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	150′	Yes	C	Yes	
E	60′	Yes	C	Yes	
S	30′	Partial 100′	C	Yes	All exposures burned
W	60′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposures.

VERTICAL FIRE SPREAD: No.

EXTENT OF FIRE: Total floor area: 16,200 square feet. Floor area burned: 0 square feet; 0 percent (after blast damage).

REMARKS: Sparks from south exposure ignited few pieces of furniture in first and third stories and cotton blackout curtains in first story about 1030 hours. Fires were extinguished with water buckets by people inside. Negligible fire damage resulted. Some of exposing buildings had just been removed prior to the bomb.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 61. Coordinates: 51. Distance from (GZ): 3,400, (AZ): 4,000.

NAME: Hiroshima Radio Station:

CONSTRUCTION AND DESIGN

Type: Reinforced-concrete frame.

Number of stories: 2. JTG class: E1.

Roof: Reinforced-concrete beam and slab.

Partitions: 4-inch reinforced concrete ⅜–9 inches O. C.

Walls: 8-inch reinforced concrete—moderate openings.

Floors: Reinforced concrete.

Framing: Reinforced-concrete beam and slab.

Window and door frames: Steel. Ceilings: Unknown.

Condition, workmanship, and materials: Poor, concrete poor, reinforcement exposed in many places, form work poor.

Compare with usual United States buildings: Somewhat heavier than United States design.

OCCUPANCY: Broadcasting studio.

CONTENTS:

DAMAGE to building: Small panel of first floor depressed 4 to 6 inches in front of door. Two non-load-bearing partitions blown out. Minor damage throughout. Sash blown out, trim and finish burned out.

Cause: Blast.

To contents: Completely destroyed.

Cause: Fire (may have been some debris damage).

TOTAL FLOOR AREA (square feet): 8,300. Structural damage: —. Superficial damage: —.

FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents: 100 percent.

REMARKS: Water pipes in second floor ruptured at one point. General condition and construction of building was very poor.

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 61. Fire classification: R.

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	No			
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	60'	Yes	C	Yes	
E	15'	No	C	Yes	
S	80'	Yes	C	Yes	
W	40'	No	C	Yes	

PROBABLE CAUSE OF FIRE: Not determined.

VERTICAL FIRE SPREAD: Possibly.

EXTENT OF FIRE: Total floor area: 8.300 square feet. Floor area burned 8,300 square feet; 100 percent (after blast damage).

REMARKS: Some of exposing buildings were just being removed at time of bomb.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 86. **Coordinates:** 5G. **Distance from (GZ):** 2,000, **(AZ):** 2,800.

NAME: Kōkō Private Grammar School.

CONSTRUCTION AND DESIGN

Type: Reinforced concrete.

Number of stories: Three. **JTG class:** E1.

Roof: Reinforced-concrete slab.

Partitions: 9-inch brick and 6-inch reinforced concrete.

Walls: Reinforced concrete (8–10 inches).

Floors: Reinforced concrete, wood finish on sleepers.

Framing: Reinforced concrete.

Window and door frames: Wood. **Ceilings:** Wood lath and plaster.

Condition, workmanship, and materials:

Compare with usual united States buildings: Stronger and heavier.

OCCUPANCY: School.

CONTENTS: Classroom furnishings, equipment, and office furnishings.

DAMAGE to building: One roof girder cracked, 9-inch brick partition in first story fractured at ceiling, hung ceiling destroyed. All sash blown out, doors and trim damaged. Outside toilet at west end of building collapsed.

Cause: Blast.

To contents: Furnishings and other contents cut by glass and debris and broken by tumbling around by blast.

Cause: Blast and debris (about equally).

TOTAL FLOOR AREA (square feet): 11,500. **Structural damage:** 500. **Superficial damage:**

FRACTION OF DAMAGE: Building structural: 4 percent. Superficial: —. Contents: 20–40 percent.

REMARKS: Lean-to toilet in which all structural damage occurred, was of weaker construction than rest of building.

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 86. **Fire classification:** R.

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	No		
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Class	Fire Burned	Remarks
N	125′	Yes	C	Yes	
E	150′	Yes	C	Yes	Blank wall except fire escape exits.
S	125′	Yes	C	Yes	
W	125′	Yes	C	Yes	Blank wall.

PROBABLE CAUSE OF FIRE: No fire.

VERTICAL FIRE SPREAD:

EXTENT OF FIRE: Total floor area: 11,500 square feet. Floor area burned: 0 square feet; 0 percent (after blast damage).

REMARKS: Extended east-west axis of building would pass approximately through zero point. East wall, which faced zero point was blank except for exit at each story to fire escape. If doors at fire escape were closed at time of bomb, probably the interior of the building was shielded from direct radiated heat from the bomb

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 87-A. Coordinates: 7F. Distance from (GZ): 8,000, (AZ): 8,200.
NAME: Funairi Grammar School.
CONSTRUCTION AND DESIGN
Type: Wood frame.
Number of stories: Two. JTG class: E2.
Roof: Asbestos cement on wood trusses and wood sheathing.
Partitions: Wood.
Walls: Wood lath and plaster with wood exterior.
Floors: Wood over wood framing.
Framing: Wood.
Window and door frames: Wood. Ceilings: Wood.
Condition, workmanship, and materials: Good, but design rather poor.
Compare with usual United States buildings: Weaker because of very slender columns and poor joints.
OCCUPANCY: Classrooms.
CONTENTS: Classroom furnishing and equipment.
DAMAGE to building: Entire building on verge of collapse, and one wing completely collapsed. Walls and columns facing blast buckled and building displaced away from blast.
Cause: Blast.
To contents: Most of contents were severely damaged by debris and by being overturned and blown about by blast.
Cause: Blast and debris (about equally).
TOTAL FLOOR AREA (square feet): 38,400. Structural damage: 38,400. Superficial damage:
FRACTION OF DAMAGE: Building structural: 100 percent. Superficial: . Contents: 50 percent.
REMARKS: Fire walls were of reinforced concrete.

NOTE. Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 1

Building No.: 87-B. Coordinates: 7F. Distance from (GZ): 8,000, (AZ): 8,200.
NAME: Funairi Grammar School.
CONSTRUCTION AND DESIGN
Type: Light steel frame.
Number of stories: One. JTG class: A2 2.
Roof: Asbestos shingles over wood-sheathing and purlins.
Partitions: None.
Walls: Plaster on wood lath with wood exterior sheathing.
Floors: Wood over wood beams on concrete posts.
Framing: Light steel-trussed arch.
Window and door frames: Wood. Ceilings: None.
Condition, workmanship, and materials: Good.
Compare with usual United States buildings: Slightly lighter design but generally comparable.
OCCUPANCY: School auditorium.
CONTENTS: Lectern, benches, tables, teaching aids.
DAMAGE to building: Roof trusses slightly deformed but probably will be used in place. Most of roofing stripped or displaced. Wall facing blast blown in.
Cause: Blast.
To contents: Slight damage and that primarily due to exposure.
Cause: Exposure.
TOTAL FLOOR AREA (square feet): 4,900. Structural damage: . Superficial damage: 4,900.
FRACTION OF DAMAGE: Building structural: Superficial: 100 percent. Contents: 10 percent.
REMARKS:

NOTE. Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 95. **Coordinates:** 4G. **Distance from (GZ):** 1,200, **(AZ):** 2,300.
NAME: Honkawa Grammar School.
CONSTRUCTION AND DESIGN
Type: Reinforced concrete.
Number of stories: Three and basement. **JTG class** E1.
Roof: Reinforced concrete, cement finish.
Partitions: Reinforced concrete (7-inch).
Walls: Reinforced concrete (10-inch).
Floors: Reinforced concrete, wood finish on sleepers.
Framing: Reinforced concrete.
Window and door frames: Metal. **Ceilings:** Plaster on concrete.
Condition, workmanship, and materials: Excellent.
Compare with usual United States buildings: Stronger.
OCCUPANCY: School classrooms.
CONTENTS: School furnishings and equipment.
DAMAGE to building: Panel walls facing blast buckled. One roof girder structurally damaged and slab depressed. About 15 percent of roof slabs cracked and beams cracked with some spalling but usable in place. All finish, floors and trim burned out, sash and doors blown out.
Cause: Blast.
To contents: Completely destroyed.
Cause: Fire (primary) may have been some debris damage.
TOTAL FLOOR AREA (square feet): 49,500. **Structural damage:** 500. **Superficial damage:** 3,000.
FRACTION OF DAMAGE: Building structural: 1 percent. Superficial: 6 percent. Contents: 100 percent.
REMARKS:

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 95. **Fire classification:** R.
WALL OPENINGS: Shutters: None.
Shut:
Effect of blast:
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Part	No		
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	125′	Yes	C		
E	—	No	—	—	No exposure.
S	30′	Partial 150′	C	Yes	All exposures burned
W	100′	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Not determined.
VERTICAL FIRE SPREAD: Probably.
EXTENT OF FIRE: Total floor area: 49,500 square feet. Floor area burned: 49,500 square feet: 100 percent (after blast damage).
REMARKS:

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building No.: 96. Coordinates: G5. Distance from (GZ): 400 (AZ): 2,000.

NAME: Taisho Clothing Store.

CONSTRUCTION AND DESIGN

Type: Reinforced concrete.

Number of stories: Three and basement. JTG class: E1.

Roof: Reinforced-concrete slabs, cement finish.

Partitions: Reinforced concrete and wood.

Walls: Reinforced concrete (10-inch), brick panels on first floor.

Floors: Reinforced concrete (wood finish on sleepers, second floor).

Framing: Reinforced concrete.

Window and door frames: Metal. Ceilings: Plaster on concrete.

Conditions, workmanship, and materials: Fair.

Compare with usual United States buildings: Considerable stronger (larger structural members).

OCCUPANCY: Mercantile.

CONTENTS: Merchandise for sale.

DAMAGE to building: All roof slabs depressed, fracturing beams and girders and stretching steel. Panel in east wall buckled, girders in second floor rear cracked and spalled. Ninety percent of parapet demolished. All sash and doors blown out. Finish and trim burned out. No fire in basement.

Cause: Blast.

To contents: Completely destroyed, except in basement

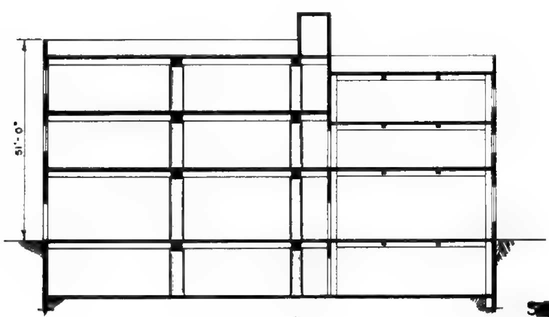
Cause: Fire (primary cause—probably some debris damage).

TOTAL FLOOR AREA (square feet): 12,400. Structural damage: 3,900. Superficial damage:

FRACTION OF DAMAGE: Building structural: 31 percent. Superficial: —. Contents: 75 percent.

REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.



SECTION "A-A"

[redacted]

U.S. STRATEGIC BOMBING SURVEY
BUILDING 96
HIROSHIMA, JAPAN GRID 5H
FIGURE 100-X A

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 96. Fire classification: R.

WALL OPENINGS: Shutters: None.

Shut:

Effect of blast:

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	No			
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Fire Glass	Burned	Remarks
N	35'	No	C	Yes	
E	10'	No	C	Yes	
S	10'	No	C	Yes	
W	150'	Yes	C	Yes	

PROBABLE CAUSE OF FIRE: Not determined.

VERTICAL FIRE SPREAD: Possibly.

EXTENT OF FIRE: Total floor area: 12,400 square feet. Floor area burned: 9,300 square feet; 75 percent (after blast damage).

REMARKS: Fire throughout building except in basement

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Sheet No. 1

Building N8.: 100. **Coordinates:** 5G. **Distance from (GZ):** 800, **(AZ):** 2,100.
NAME: Nippon Simple Fire Insurance Co.
CONSTRUCTION AND DESIGN
Type: Reinforced-concrete frame.
Number of stories: 2. **JTG class:** E2.
Roof: Reinforced-concrete slab and beams.
Partitions: None.
Walls: Reinforced concrete, stucco finish.
Floors: Reinforced-concrete slab, cement finish.
Framing: Reinforced concrete.
Window and door frames: Metal. **Ceilings:** Plaster on concrete.
Condition, workmanship, and materials: Good.
Compare with usual United States buildings: Comparable.
OCCUPANCY: Office.
CONTENTS: Office furnishings and equipment.
DAMAGE to building: One roof girder cracked and spalled. Sash and doors blown out or deformed. Trim and finish damaged by fire.
Cause: Blast.
To contents: Completely destroyed.
Cause: Fire (probably appreciable blast and debris damage).
TOTAL FLOOR AREA (square feet): 3,000. **Structural damage:** —. **Superficial damage:** 80.
FRACTION OF DAMAGE: Building structural: —. Superficial: 3 percent. Contents: 100 percent.
REMARKS:

Note.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

Sheet No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 100. **Fire classification:** R.
WALL OPENINGS: Shutters: No.
Shut:
Effect of blast:
FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	No			
Elevators:				

EXPOSURE:

Location	Distance	Firebreak Clearance	Class	Fire Burned	Remarks
N	0'	No	C	Yes	Door blown off or bent.
E	15'	No	C	Yes	
S	40'	No	C	Yes	
W	0'	No	C	Yes	Blank wall.

PROBABLE CAUSE OF FIRE: Not determined.
VERTICAL FIRE SPREAD: Possibly.
EXTENT OF FIRE: Total floor area: 3,000 square feet. Floor area burned: 3,000 square feet 100 percent (after blast damage).
REMARKS: East wall which faced zero point was blank and it is believed the interior of the building was shielded from direct radiated heat from the bomb.

U. S. STRATEGIC BOMBING SURVEY

PHYSICAL DAMAGE DIVISION

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

SHEET No. 1

Building No.: 122. Coordinates: 5J. Distance from (GZ): 6,400, (AZ): 6,700.

NAME: Sumitomo Bank Co., Higashi Matsurara Branch.

CONSTRUCTION AND DESIGN

Type: Protected steel frame.

Number of stories: 2. JTG class: E1.

Roof: Reinforced-concrete slab on steel beams.

Partitions: Plaster on metal lath.

Walls: Brick panel—13-inch.

Floors: Reinforced-concrete slab and beams.

Framing: Steel—protected.

Window and door frames: Wood. Ceilings: Plaster on concrete.

Condition, workmanship, and materials: Excellent.

Compare with usual United States buildings: Slightly heavier.

OCCUPANCY: Bank with offices on second floor.

CONTENTS: Office and banking equipment.

DAMAGE to building: Glass blown out, few shutters facing blast deformed.

Cause: Blast.

To contents: None.

Cause:

TOTAL FLOOR AREA (square feet): 5,100. Structural damage: —. Superficial damage:

FRACTION OF DAMAGE: Building structural: —. Superficial: —. Contents:

REMARKS:

NOTE.—Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

SHEET No. 2

(Fire Supplement to Sheet No. 1)

Building No.: 122. Fire classification: R.

WALL OPENINGS: Shutters: Steel rollers and hinged shutters.

Shut:

Effect of blast: Part bent in slightly.

FLOOR OPENINGS:

	Enclosed	Fire doors	Automatic	Effect of blast
Stairs:	Yes	No		
Elevators:				

EXPOSURE:

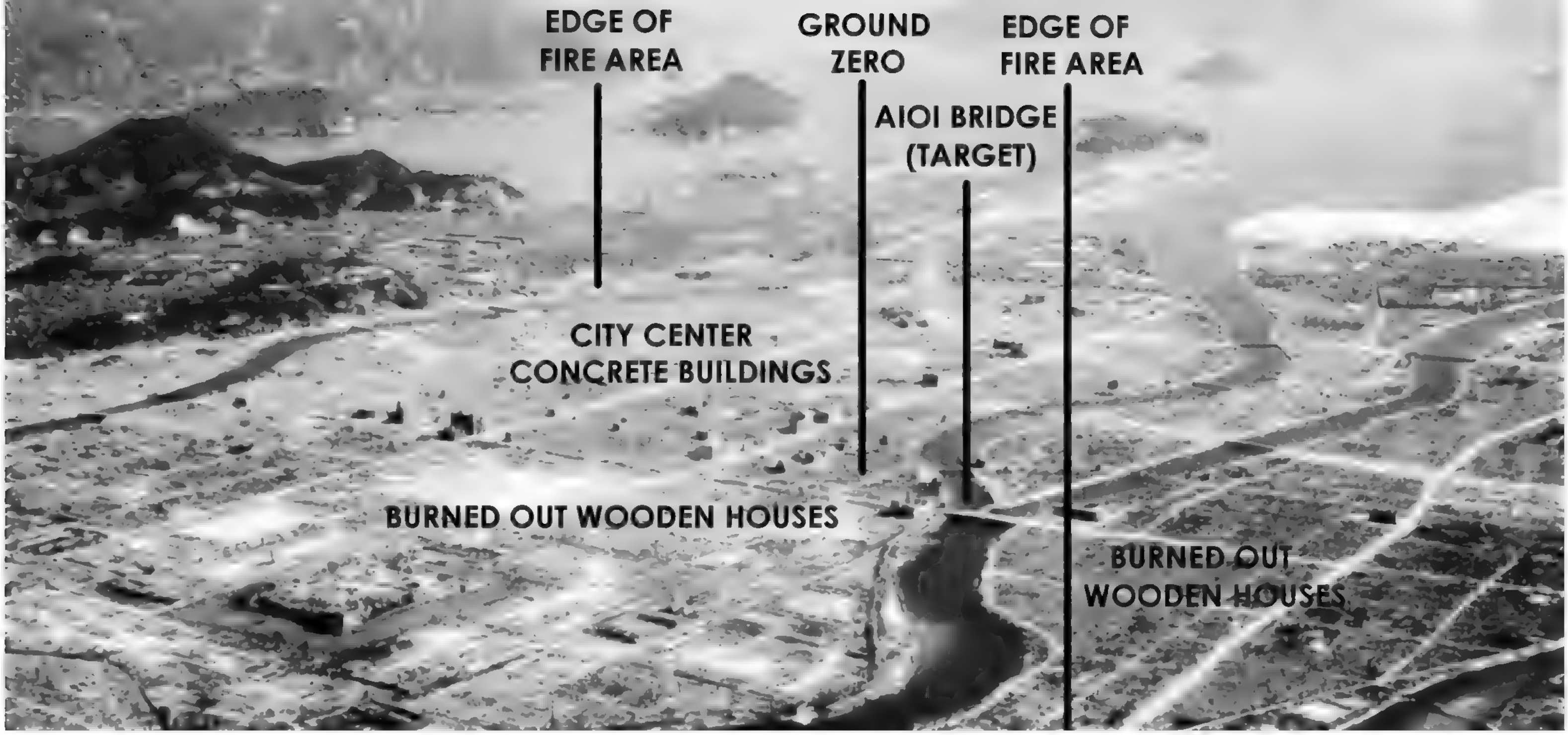
Location	Distance	Firebreak Clearance	Fire Class	Burned	Remarks
N	15'	No	C	Yes	Conn. by C pass metal and W. G. doors stopped fire.
E	200'	Yes	C	Yes	
S	--	Yes	--		No exposure.
W	5'	No	C	Yes	

PROBABLE CAUSE OF FIRE: Fire spread from exposures.

VERTICAL FIRE SPREAD: No.

EXTENT OF FIRE: Total floor area: 5,100 square feet. Floor area burned: 0 square feet; 0 percent (after blast damage).

REMARKS: Fire spread into building from exposures at west wall and northeast corner. Fires were extinguished by people inside and negligible damage was done.


EDGE OF FIRE AREA
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EDGE OF FIRE AREA
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CITY CENTER CONCRETE BUILDINGS
BURNED OUT WOODEN HOUSES
BURNED OUT WOODEN HOUSES


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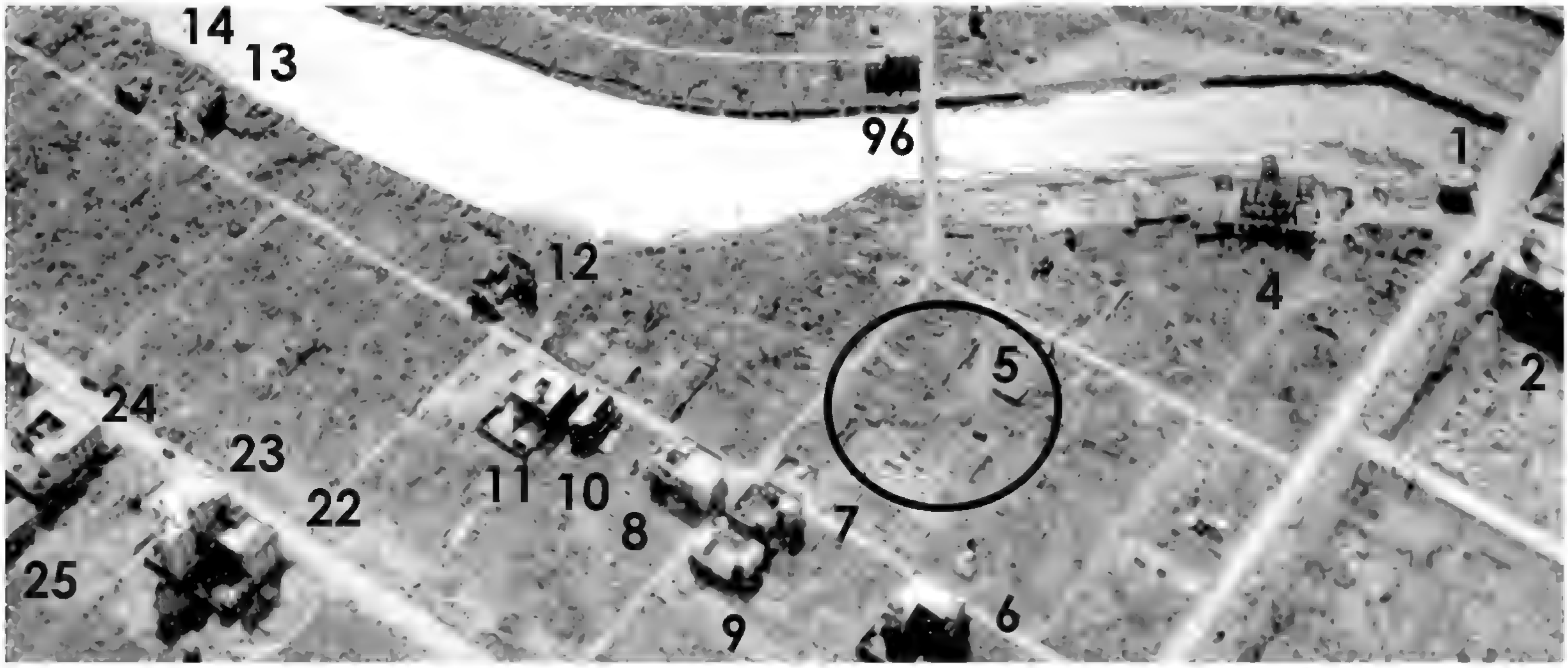
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5th Field Artillery Regiment
Imperial Hq
5th Division Hq
Clothing Warehouse
Military Academy
11th Infantry Regiment
Revenue Office
Regimental Headquarters
NISHI DRILL FIELD
Division Commanders' Quarters
Electric Transformer Station
Saibi Grade School
Officers' Club
Military Police
SARUGAKUCHO
HATCHOBORI
TOGIYACHO
Dept. Store
TAKAJO-MACHI
Honkawa Grade School
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AIOI BASHI
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ABURAYACHO
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Commercial Display Hall
NAKAJIMA-HOMMACHI
HONKAWA-BASHI
MOTOYASU-BASHI
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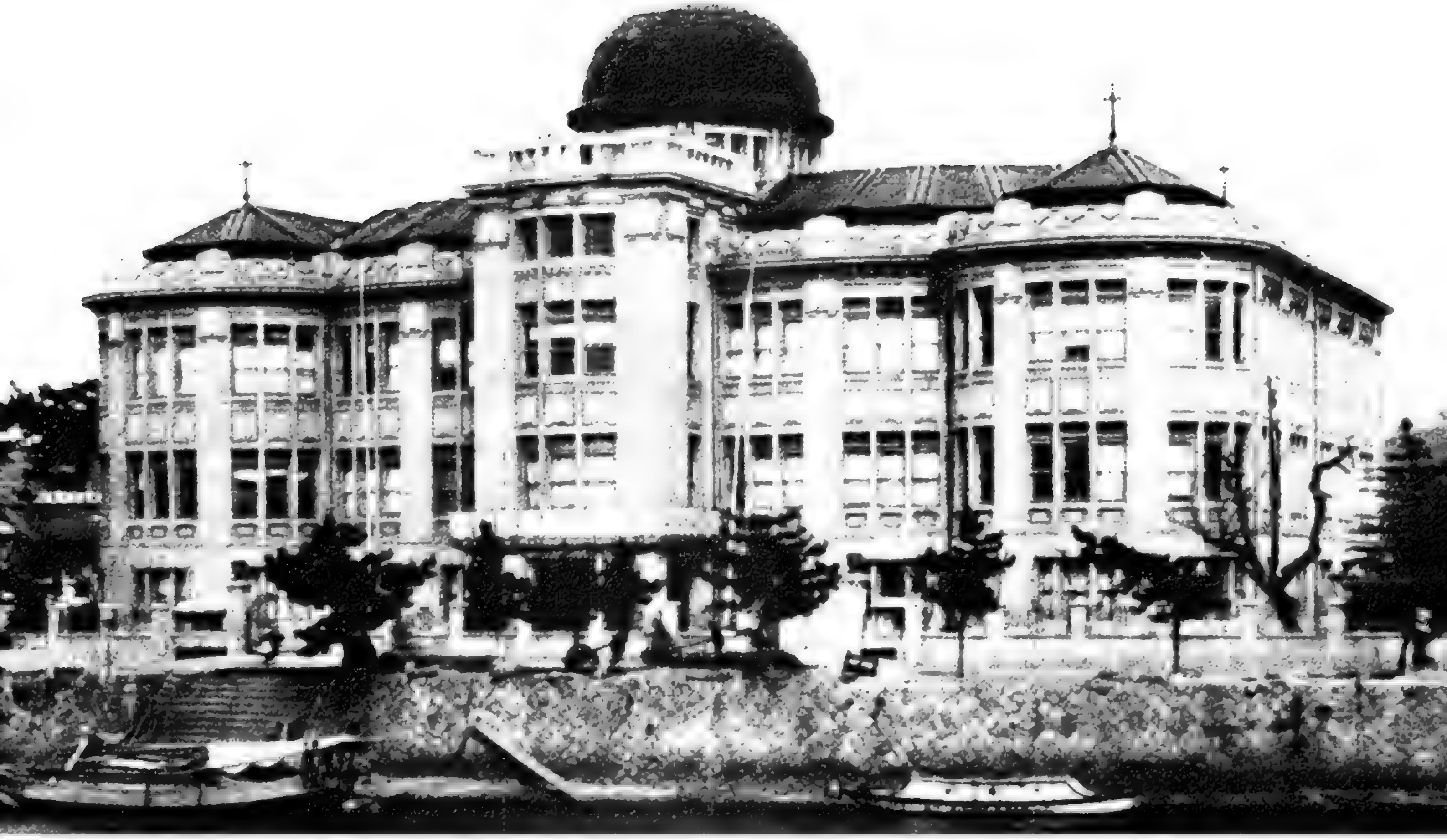
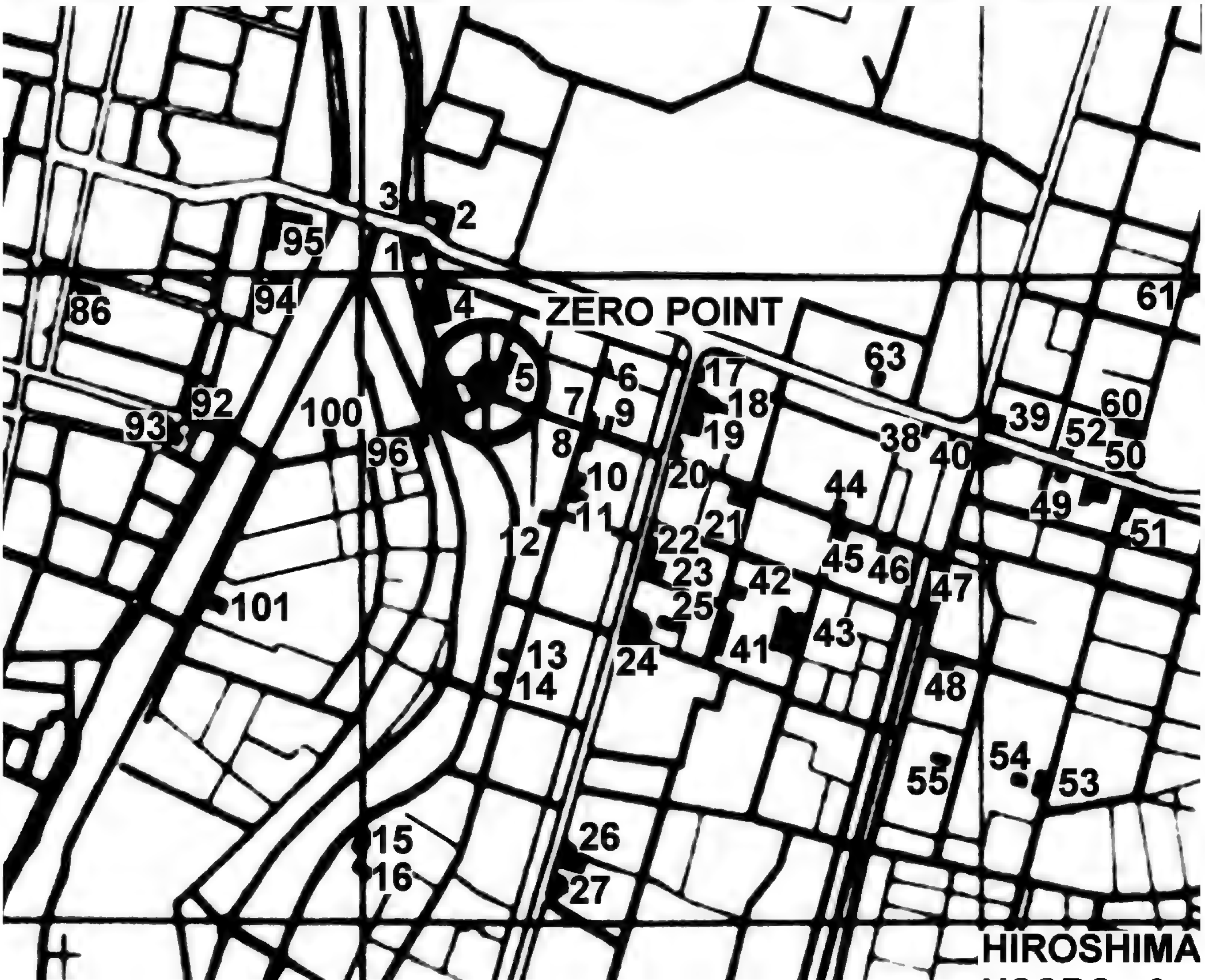
Nishio Mat Factory
NISHI-JIKATA-MACHI
FIRE LANE
TSUKAMOTOCHO
ZAI-MOKU-CHO
ONOMICHICHO
SHIN-BASHI
Kokutai-ji
Telephone Office
Fish Market
EBISUCHO
TATEMACHI
SHIN-O-HASHI
NAKAJIMA-SHIMMACHI
KOBIKICHO
Hotel
Court of Appeals
Girls High School
SHIMONAKACHO
HORIKAWA-CHO
MIKAWACHO
SHIMO-NAGAREKAWACHO
Court
KO-MACHI
Prefectural Hospital
Electric Substation
Elec Co
Bank of Japan
ŌTEMACHI
Asano Library
Prefectural Office
Nakajima Grade School
BANTAI-BASHI
Public Hall
Daiichi Middle School
TAKEYACHO
TANAKA-MACHI
Commercial School
ATHLETIC FIELD
Ote Grade School
Sanyō Middle School
KOKUTAIJIMACHI
ZAKOBACHO
TAKARAMACHI
Girls' High School
Fish Market
Commercial School
Paper Mill
MEIJI-BASHI
City Hall
NISHI-KUKENCHO
NISHI-HIKIMIDOCHO
HIROSE KITAMACHI
SOROZAYACHO
Hirose Grade School



Commercial Museum (300 meters) before and after


1000'


ZERO POINT
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THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume III

Physical Damage Division

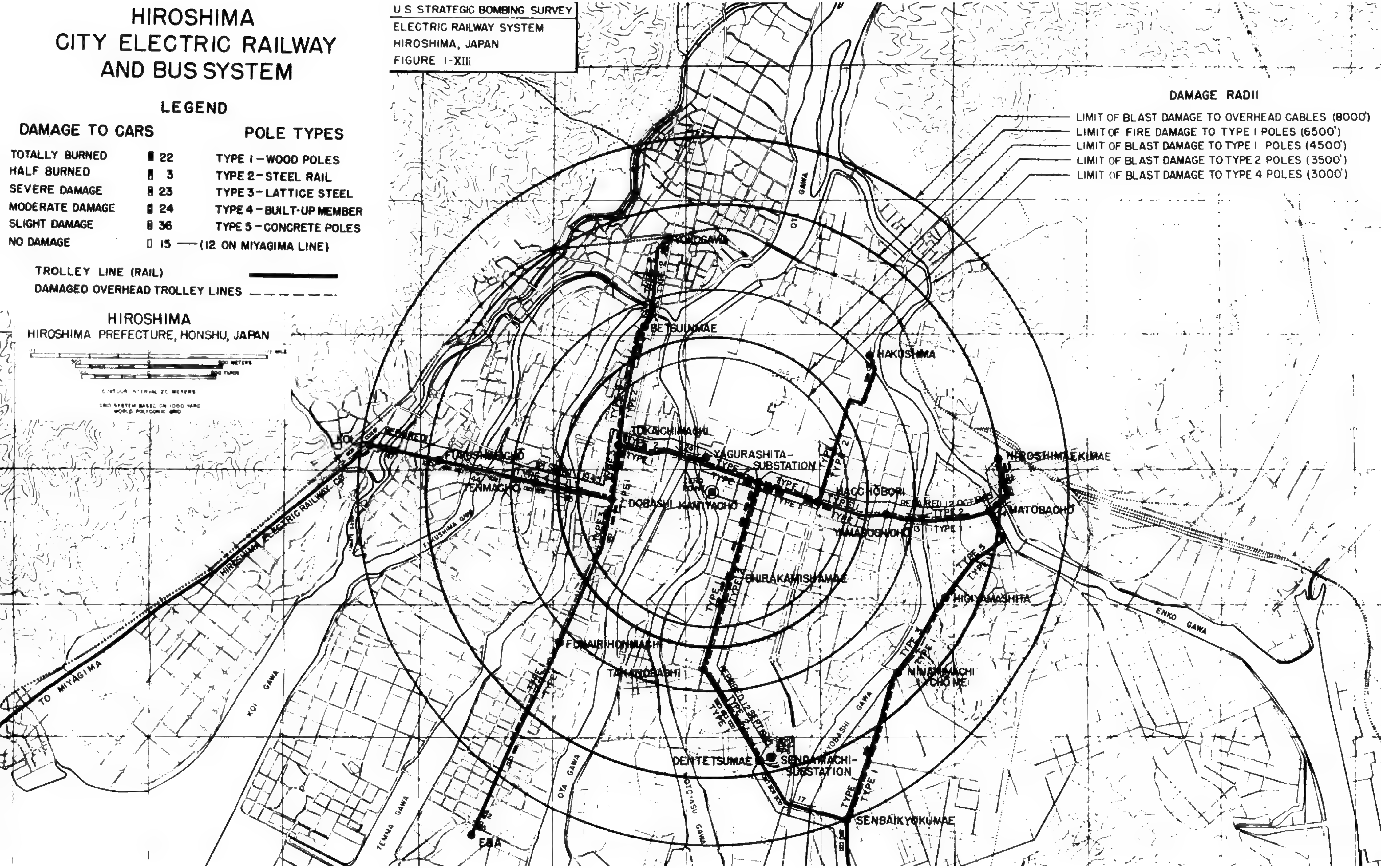
Dates of Survey:

14 October – 26 November 1945

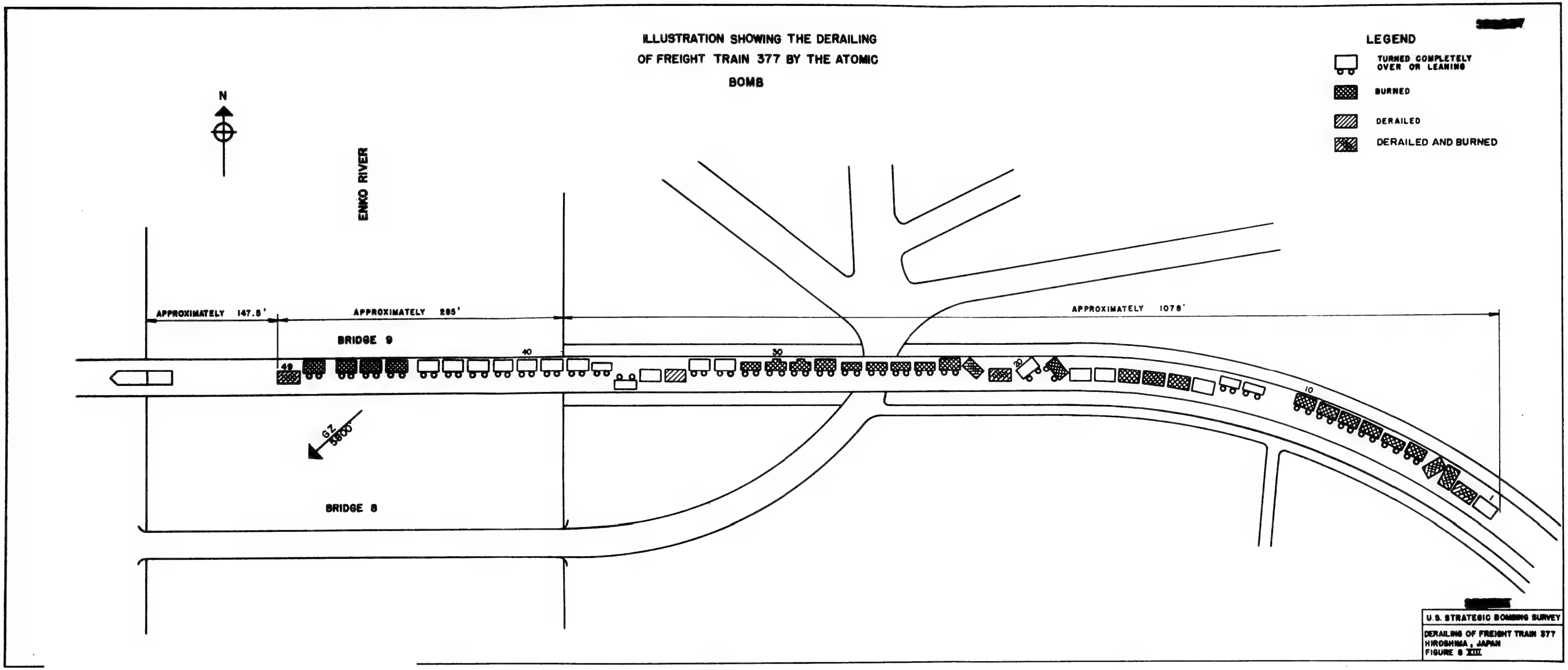
Date of Publication
May 1947

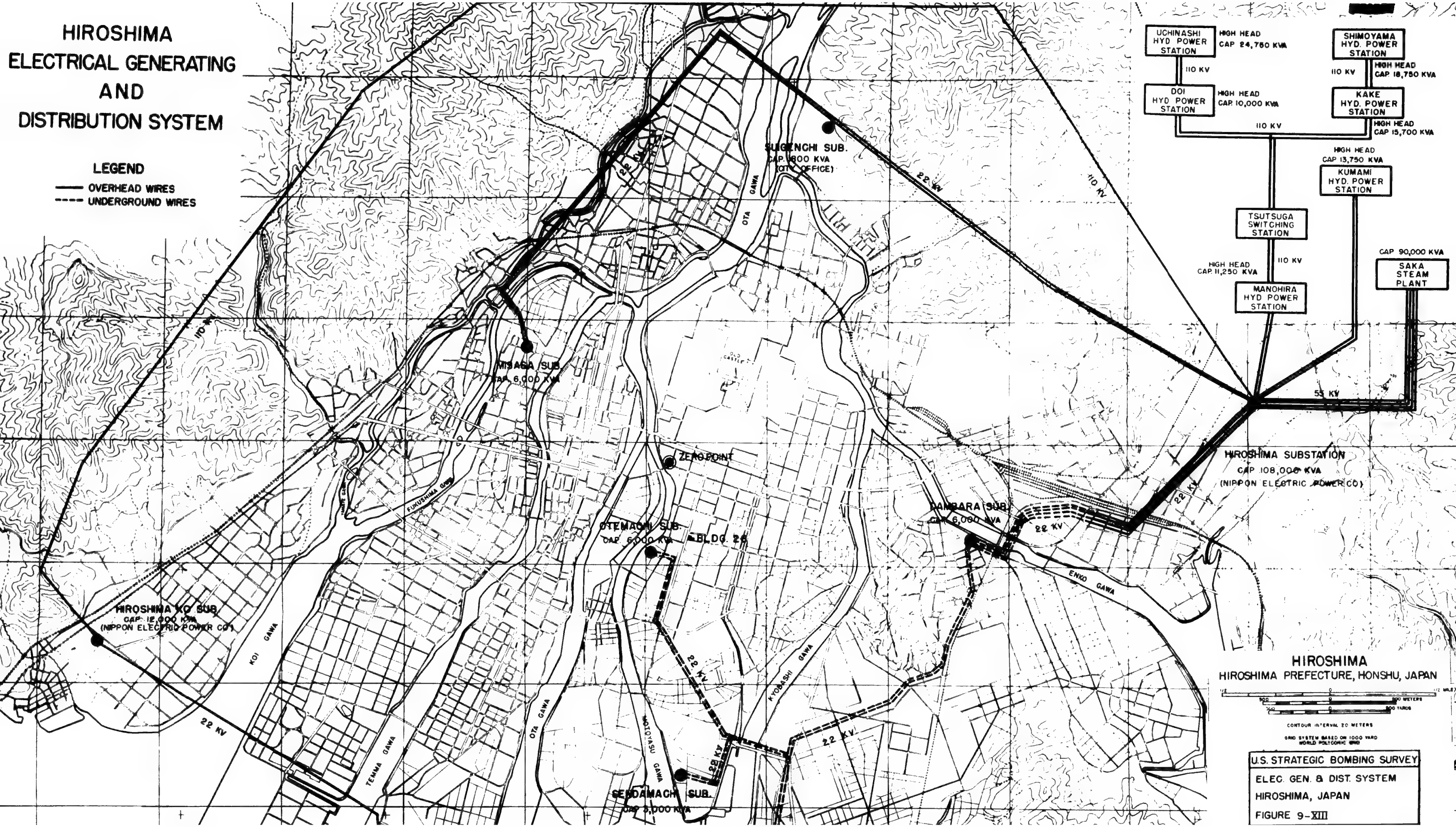
[redacted]

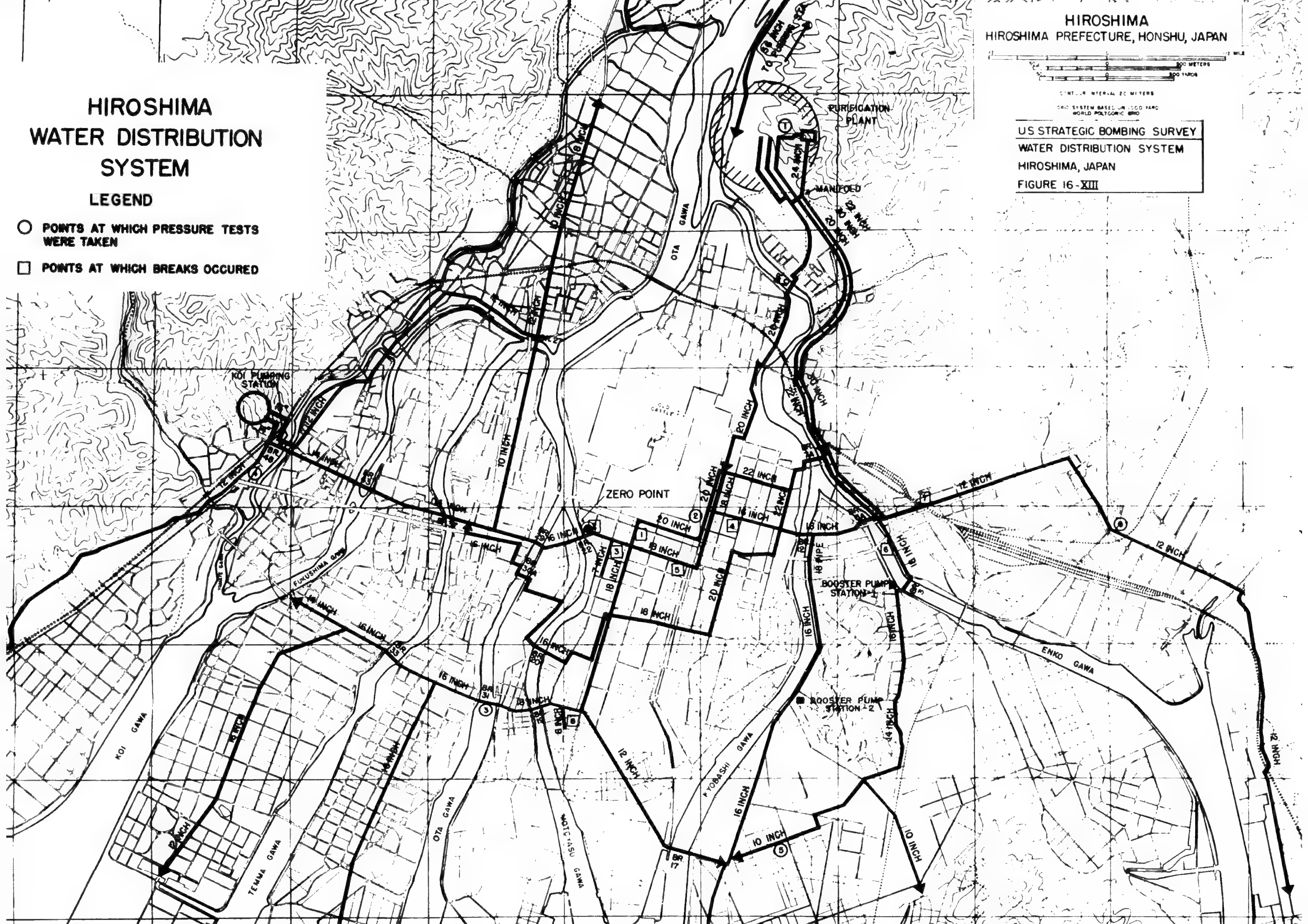

(1,000 ft GZ)
AIOI BRIDGE



HIROSHIMA
CITY ELECTRIC RAILWAY
AND BUS SYSTEM
LEGEND
DAMAGE TO CARS
TOTALLY BURNED 22
HALF BURNED 3
SEVERE DAMAGE 23
MODERATE DAMAGE 24
SLIGHT DAMAGE 36
NO DAMAGE 15 — (12 ON MIYAGIMA LINE)
POLE TYPES
TYPE 1 – WOOD POLES
TYPE 2 – STEEL RAIL
TYPE 3 – LATTICE STEEL
TYPE 4 – BUILT-UP MEMBER
TYPE 5 – CONCRETE POLES
TROLLEY LINE (RAIL)
DAMAGED OVERHEAD TROLLEY LINES
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
U.S. STRATEGIC BOMBING SURVEY
ELECTRIC RAILWAY SYSTEM
HIROSHIMA, JAPAN
FIGURE I-XIII
DAMAGE RADII
LIMIT OF BLAST DAMAGE TO OVERHEAD CABLES (8000')
LIMIT OF FIRE DAMAGE TO TYPE 1 POLES (6500')
LIMIT OF BLAST DAMAGE TO TYPE 1 POLES (4500')
LIMIT OF BLAST DAMAGE TO TYPE 2 POLES (3500')
LIMIT OF BLAST DAMAGE TO TYPE 4 POLES (3000')
YOKOGAWA
BETSUINMAE
HAKUSHIMA
TOKAICHIMACHI
YAGURASHITA-SUBSTATION
HACCHOBORI
HIROSHIMAEKIMAE
MATOBACHO
YAMAGUCHICHO
DOBASHI
KAMIYACHO
FUKUSHIMACHO
TENMACHO
KOI
HIROSHIMA ELECTRIC RAILWAY CO.
TO MIYAGIMA
SHIRAKAMISHAMAE
HIGIYAMASHITA
FUNAIRIHONMACHI
TAKANOBASHI
MINAMIMACHI
DENTETSUMAE
SENDAMACHI-SUBSTATION
SENBAIKYOKUMAE
EBA
ENKO GAWA
KOI GAWA
OTA GAWA
TEMMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA


[redacted]
ILLUSTRATION SHOWING THE DERAILING
OF FREIGHT TRAIN 377 BY THE ATOMIC
BOMB
LEGEND
TURNED COMPLETELY OVER OR LEANING
BURNED
DERAILED
DERAILED AND BURNED
N
ENKO RIVER
APPROXIMATELY 147.8'
APPROXIMATELY 285'
APPROXIMATELY 1078'
BRIDGE 9
BRIDGE 8
49
40
30
20
10
1
GZ 5800
[redacted]
U.S. STRATEGIC BOMBING SURVEY
DERAILING OF FREIGHT TRAIN 377
HIROSHIMA, JAPAN
FIGURE 8 XIII


HIROSHIMA
ELECTRICAL GENERATING
AND
DISTRIBUTION SYSTEM
LEGEND
OVERHEAD WIRES
UNDERGROUND WIRES
UCHINASHI HYD POWER STATION
HIGH HEAD CAP 24,750 KVA
110 KV
DOI HYD POWER STATION
HIGH HEAD CAP 10,000 KVA
SHIMOYAMA HYD. POWER STATION
110 KV
HIGH HEAD CAP 18,750 KVA
KAKE HYD. POWER STATION
HIGH HEAD CAP 15,700 KVA
110 KV
HIGH HEAD CAP 13,750 KVA
KUMAMI HYD. POWER STATION
TSUTSUGA SWITCHING STATION
110 KV
HIGH HEAD CAP 11,250 KVA
MANOHIRA HYD POWER STATION
CAP 90,000 KVA
SAKA STEAM PLANT
55 KV
110 KV
22 KV
HIROSHIMA SUBSTATION
CAP 108,000 KVA
(NIPPON ELECTRIC POWER CO)
SUIGENCHI SUB.
CAP 1800 KVA
(CITY OFFICE)
MISASA SUB.
CAP 6,000 KVA
ZERO POINT
OTEMACHI SUB.
CAP 6,000 KVA
BLDG 26
DAMBARA SUB.
CAP 6,000 KVA
SENDAMACHI SUB.
CAP 3,000 KVA
HIROSHIMA KO SUB.
CAP 12,000 KVA
(NIPPON ELECTRIC POWER CO)
OTA GAWA
KOI GAWA
TEMMA GAWA
FUKUSHIMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
U.S. STRATEGIC BOMBING SURVEY
ELEC. GEN. & DIST. SYSTEM
HIROSHIMA, JAPAN
FIGURE 9-XIII


HIROSHIMA
WATER DISTRIBUTION
SYSTEM
LEGEND
POINTS AT WHICH PRESSURE TESTS WERE TAKEN
POINTS AT WHICH BREAKS OCCURED
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
US STRATEGIC BOMBING SURVEY
WATER DISTRIBUTION SYSTEM
HIROSHIMA, JAPAN
FIGURE 16-XIII
PURIFICATION PLANT
MANIFOLD
KOI PUMPING STATION
ZERO POINT
BOOSTER PUMP STATION-1
BOOSTER PUMP STATION-2
OTA GAWA
ENKO GAWA
KYOBASHI GAWA
MOTOYASU GAWA
TEMMA GAWA
KOI GAWA
FUKUSHIMA GAWA
12 INCH
16 INCH
18 INCH
20 INCH
22 INCH
24 INCH
30 INCH
10 INCH
14 INCH
18 PIPE

HIROSHIMA

Secondary Fires

Secondary fires are those that result from airblast damage. Their causes include overturned gas appliances, broken gas lines, and electrical short-circuits. McAuliffe and Moll (Reference 1) studied secondary fires resulting from the atomic attacks on Hiroshima and Nagasaki and compared their results with data from conventional bombings, explosive disasters, earthquakes, and tornadoes. Their major conclusion was that secondary ignitions occur with an overall average frequency of 0.006 for each 1000 square feet of floor space, provided airblast peak overpressure is at least 2 psi. The frequency of secondary ignitions appears to be relatively insensitive to higher overpressures.

Based on surveys of Hiroshima and Nagasaki buildings.

FREQUENCY OF SECONDARY IGNITIONS AS A FUNCTION OF BUILDING TYPE

Type of Structure	Frequency of Secondary Ignitions (for each 1,000 square feet of floor area)
Wood	0.019
Brick	0.017
Steel	0.004
Concrete	0.002

MULTIPLYING FACTOR FOR TYPES OF BUILDING OCCUPANCIES

Type of Occupancy	Multiplying Factor
Public	0.4
Mercantile	0.5
Residential	0.5
Manufacturing	1.0
Miscellaneous	10.0

MULTIPLYING FACTOR FOR TIME OF DAY

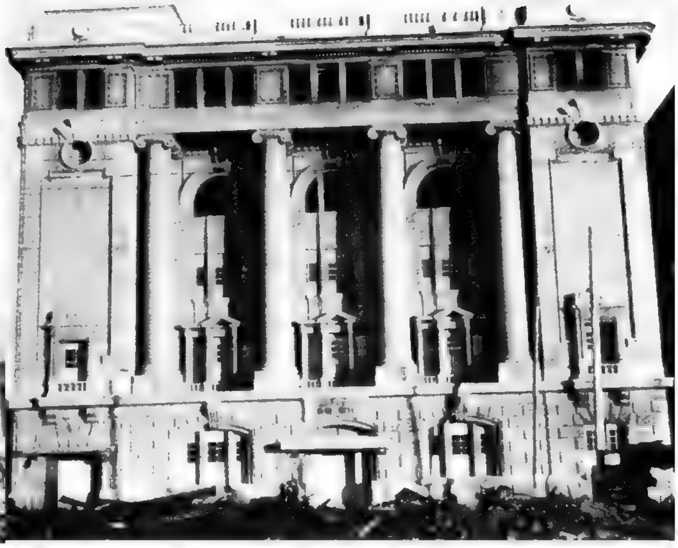
Time of Day	Multiplying Factor
Night	0.5
Day (other than mealtimes)	1.0
Mealtimes	2.0

1 . Secondary Ignitions in Nuclear Attack, J. McAuliffe and K. Moll, Stanford Research Institute, Menlo Park, California 94025, SRI Project 5106 (AD 625173), July 1965.

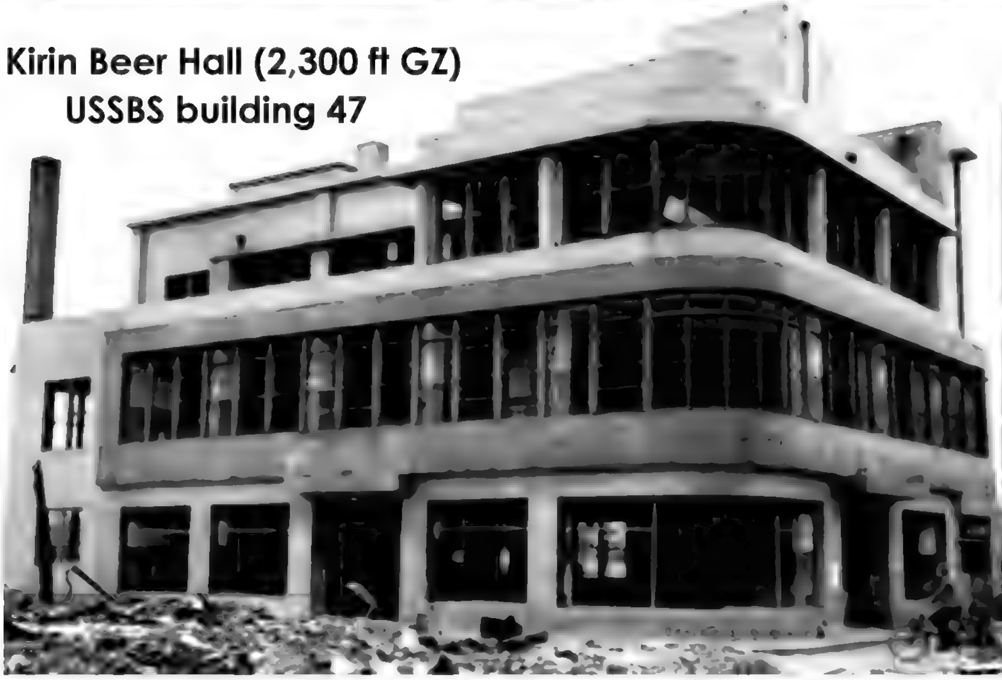
15 min. (Enola Gay)
Hiroshima fires merging

0.12 mile from GZ, Hiroshima

Geibi Bank 250 meters



Kirin Beer Hall (2,300 ft GZ)
USSBS building 47



USSBS Hiroshima building 40, Fukuya Department store 2,500 ft GZ

USSBS Hiroshima building 26
Chugoku Electric Bldg. (700 meters)

790m west of GZ, Hiroshima

Postal Savings Bureau
1 mile

USSBS building 61, J.O.F.K. Hiroshima Broadcasting Station, 900 m from GZ.

City Hall 1100 meters
USSBS Building 28

USSBS Hiroshima Building 65, 1,400 m from GZ.

USSBS Hiroshima Building 31, 1,600 m from GZ.

Red Cross Hospital


USSBS 49
Chugoku
Shimbun
3,000 ft GZ

BANK OF JAPAN BUILDING AFTER ATTACK ON HIROSHIMA

GEIBI BANK CO. BUILDING AFTER ATTACK ON HIROSHIMA

Bank of Japan: USSBS Building 24, 1300 ft from GZ
Geibi Bank Co: USSBS Building 59, 4100 ft from GZ
(Table 5 of USSBS report 92 Hiroshima, v2.)

In both, survivors extinguished fire with water buckets.

(Ref: Panel 26 of the "DCPA Attack Environment Manual", Chapter 3.)

USSBS Report 92, v2 Hiroshima buildings	MAE's in square miles	Radii of MAE's in feet
Multistory, earthquake-resistant	0. 03	500
Multistory, steel- and reinforced-concrete frame (including both earthquake- and non-earthquake-resistant construction)	. 05	700
1-story, light, steel-frame	3. 4	5, 500
Multistory, load-bearing, brick-wall	3. 6	5, 700
1-story, load-bearing, brick-wall	6. 0	7, 300
Wood-frame industrial-commercial (dimension-timber construction)	8. 5	8, 700
Wood-frame domestic buildings (wood-pole construction)	9. 5	9, 200
Residential construction	6. 0	7, 300

OFFICE OF THE AIR SURGEON

NP-3041

MEDICAL EFFECTS OF ATOMIC BOMBS

The Report of the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan; Volume VI

By

Ashley W. Oughterson
George V. LeRoy
Averill A. Liebow
E. Cuyler Hammond
Henry L. Barnett
Jack D. Rosenbaum
B. Aubrey Schneider

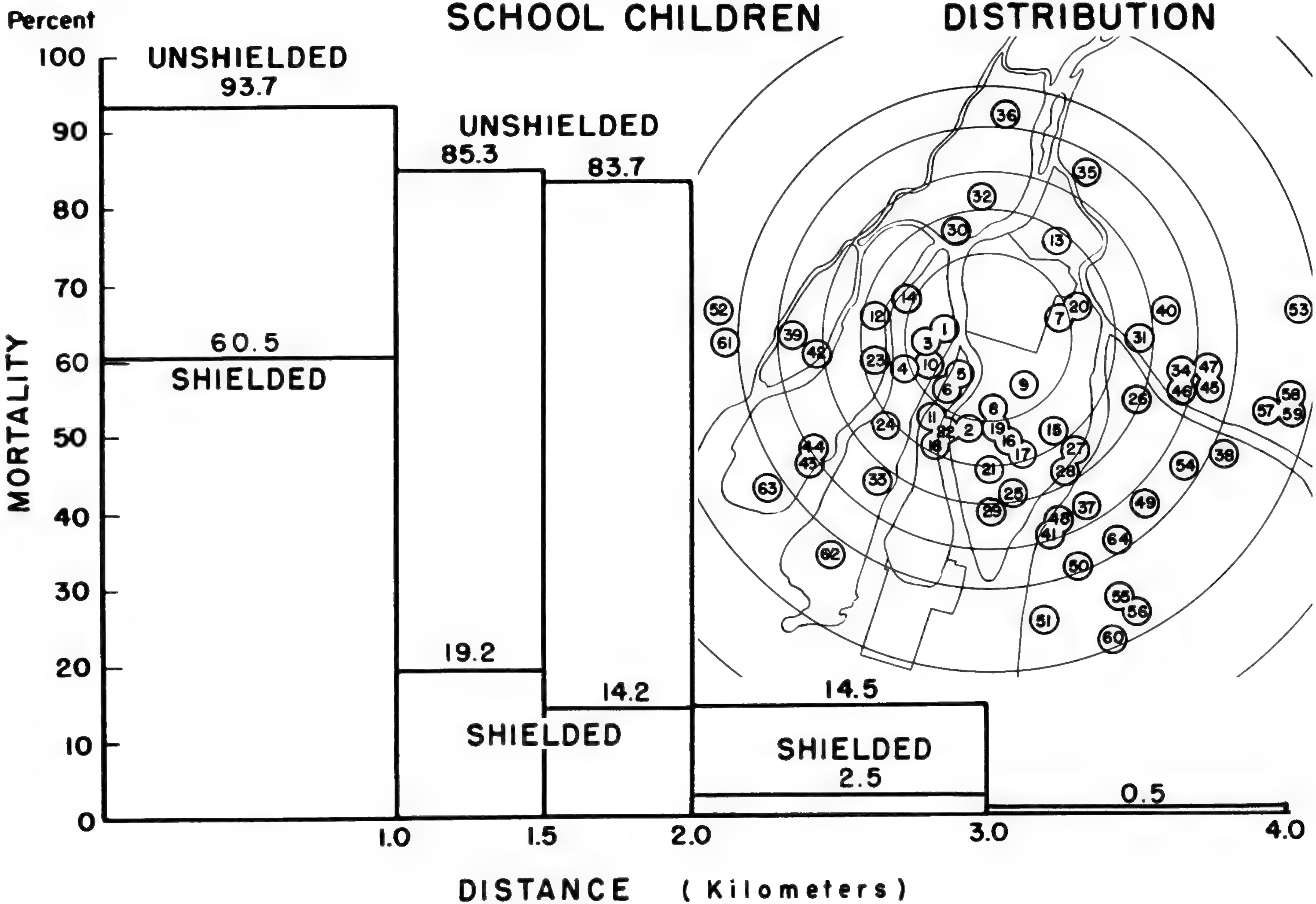
July 6, 1951
[TIS Issuance Date]

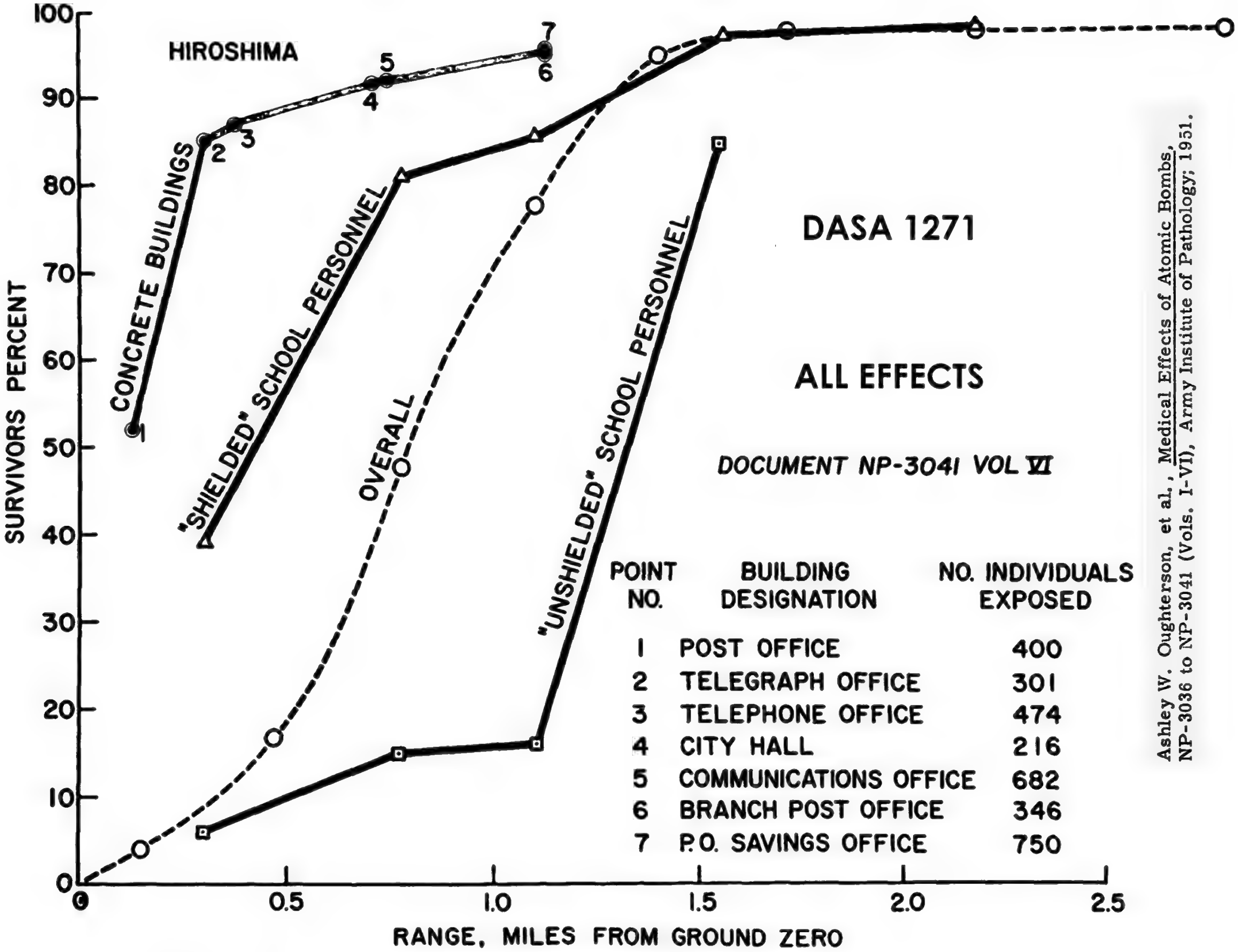
Army Institute of Pathology

UNITED STATES ATOMIC ENERGY COMMISSION
Technical Information Service, Oak Ridge, Tennessee

HIROSHIMA
SCHOOL CHILDREN

WORK PARTIES
DISTRIBUTION

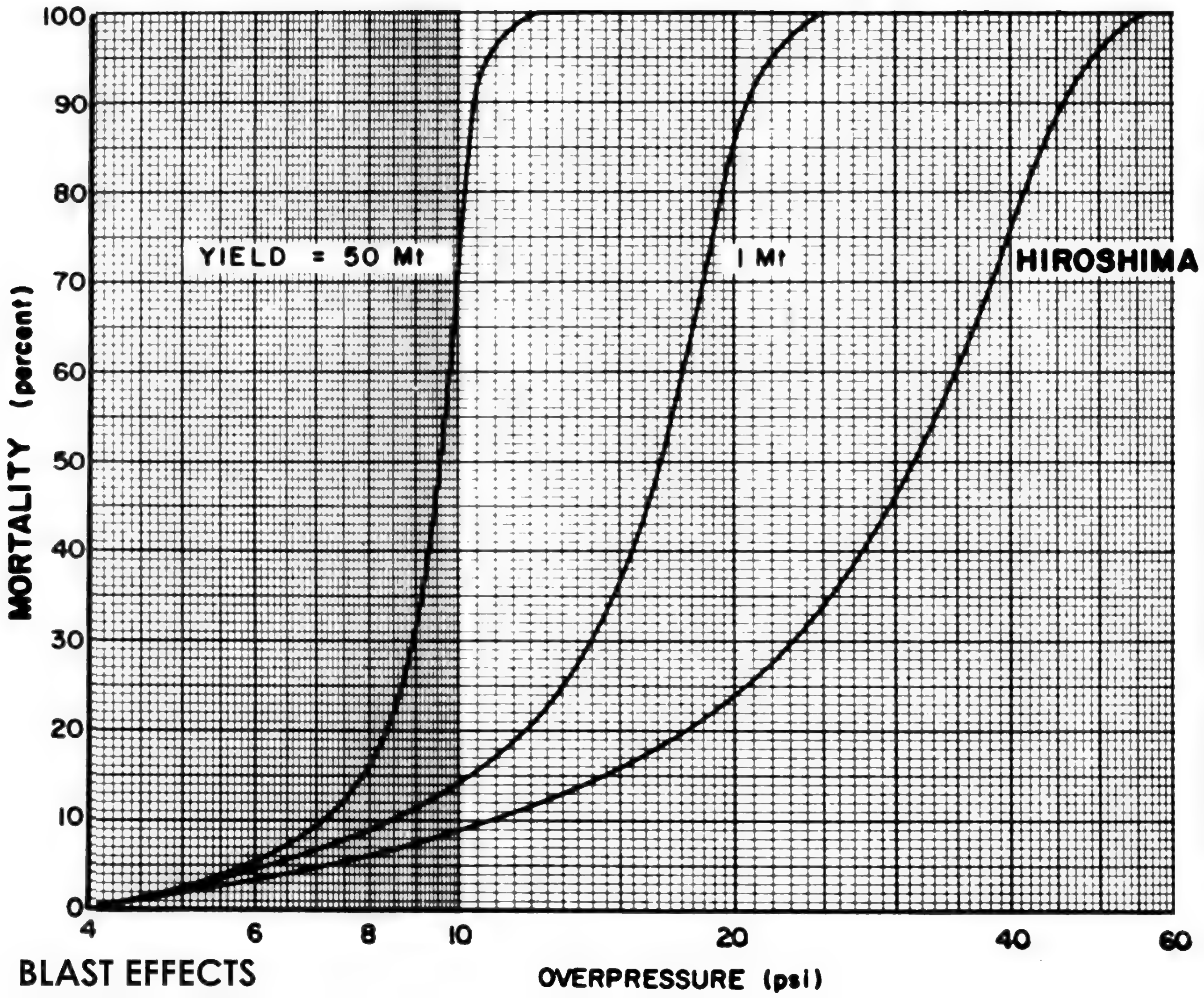




Ashley W. Oughterson, et al., Medical Effects of Atomic Bombs, NP-3036 to NP-3041 (Vols. I-VI), Army Institute of Pathology; 1951.

DC-P-1060

NONSEISMIC REINFORCED-CONCRETE BUILDINGS



BLAST EFFECTS

L. Wayne Davis, Donald L. Summers, William L. Baker, and James A. Keller, Prediction of Urban Casualties and the Medical Load from a High-Yield Nuclear Burst, DC-FR-1060, The Dikewood Corporation

MEMORANDUM
RM-3079-PR
1963

DISASTER AND RECOVERY: A HISTORICAL SURVEY

Jack Hirshleifer

PREPARED FOR:

UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation
SANTA MONICA • CALIFORNIA

As at Hamburg, people proved tougher than structures. Almost 70 per cent of the buildings in Hiroshima were destroyed, compared with around 30 per cent of population.[1]

The Research Department of the Hiroshima Municipal Office is reported to have estimated the population in the city as 407,000, in Hiroshima (Hiroshima Publishing Company, 1949).

[1]These proportions are the estimates used by the U.S. Strategic Bombing Survey report. The Hiroshima Municipal Office calculations show an even greater disparity, reporting 22 per cent of population killed and missing but some 89 per cent of buildings as destroyed or needing reconstruction (Hiroshima).

On August 7 power was generally restored to surviving areas, and through railroad service commenced on August 8. Telephone service started on August 15. Hiroshima was also not a dead city. The U.S. Strategic Bombing Survey reported that plants responsible for three-fourths of the city's industrial production could have resumed normal operations within 30 days (the newer and larger plants in Hiroshima were on the outskirts of the city, and both physical premises and personnel generally survived).[1] By mid-1949 the population had grown to over 300,000 once more, and 70 per cent of the destroyed buildings had been reconstructed.[2]

---

[1]USSBS, "The Effects of Atomic Bombs at Hiroshima and Nagasaki," p. 8.

[2]Hiroshima.

AIR WAR AND EMOTIONAL STRESS

Psychological Studies of Bombing and Civilian Defense

Irving L. Janis

The RAND Corporation

First Edition

NEW YORK • TORONTO • LONDON
McGRAW-HILL BOOK COMPANY, INC.
1951

CHAPTER 2

EMOTIONAL IMPACT OF THE A-BOMB

UNPREPAREDNESS OF THE POPULATION

At both Hiroshima and Nagasaki, disaster struck without warning. Whether intended so or not, an extraordinarily high degree of surprise was achieved by both A-bomb attacks. At the two target cities, prior to the bombing, there had been relatively little anxiety about the threat of heavy B-29 raids. When the planes carrying the A-bomb arrived over their targets, the population was almost completely unprepared. At the time, not even a light air raid was expected. People were caught at home, at work, out on the city streets, calmly going about their usual daily affairs.

When the first A-bomb was dropped, on August 6, 1945, very few residents of Hiroshima were inside air-raid shelters. An all-clear signal from a previous alert had sounded less than half an hour earlier and the normal routine of community life had resumed. Shortly after eight in the morning, when the explosion occurred, the working-class population was arriving at the factories and shops. Many workers were still out-of-doors en route to their jobs. The majority of school children, along with some adults from the suburbs, were also outside, hard at work building firebreaks as a defense against possible incendiary raids. Housewives, especially in middle-class families, were at home, preparing breakfast. Only a few minutes later, their flaming charcoal stoves were to create hundreds of local fires, adding to a general conflagration of such intensity that even if the assiduous labor of Hiroshima's school children had been completed, the fire storm still would have been beyond control.

At Nagasaki, three days later, the populace had heard only vague reports about the Hiroshima disaster. Here again, people were at

work in factories and offices, tending their homes, engaging in their normal daily activities. A few hours earlier a raid alert had been canceled; before the raid signal could be repeated, the bomb had already exploded. Only 400 people out of a population of close to a quarter of a million were inside the excellent tunnel shelters that could have protected some 75,000 people from severe injury or death.

It is generally recognized that the element of surprise was an important factor contributing to the unprecedented casualty rates at Hiroshima and Nagasaki. Many of those who were exposed to lethal gamma radiation, struck down by flying debris, or trapped in collapsed buildings would not have been killed if they had been warned in time to flee to the outskirts of the city or if they had been in adequate shelters. Thousands of people who were out-of-doors or standing in front of windows would have been protected from incapacitating flash burns if they had been under any sort of cover.[1]

Whether or not they suffered severe injury, those who survived the explosion were also affected by the element of surprise in quite another way. The absence of warning and the generally unprepared state of the population undoubtedly augmented the emotional effects of the disaster. "I was just utterly surprised and amazed and awed." This brief remark, by a newspaper reporter who was living in Nagasaki at the time of the disaster, epitomizes the way in which survivors described the terrifying events to which they were so suddenly exposed.

Of great importance in the predispositional set of the population is the fact that there was not a state of readiness to face danger or to cope with the harsh exigencies of a major catastrophe. The stage was well set for extreme emotional responses to dominate the action. It is against this background of psychological unpreparedness that the emotional impact resulting from the atomic disasters should be viewed.

---

[1] USSBS Report, *The Effects of Atomic Bombs on Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1946.

(US Strategic Bombing Survey, 1946 report "Effects of the Atomic Bombs on Hiroshima and Nagasaki", page 16)

PROTECTION AGAINST RADIANT HEAT. This patient (photographed by Japanese 2 October 1945) was about 6,500 feet from ground zero when the rays struck him from the left. His cap was sufficient to protect the top of his head against flash burns. HIROSHIMA

(Lethal 6.7 cal/sq cm, according to the 1979 US Office of Technology Assessment "Effects of Nuclear War")

Clothing protects back, 1 mile from ground zero Hiroshima, aged 17. Photo taken October 1945. Unclothed arms burned facing burst.

Above and below: clothing fails to ignite on mannequins located at 7000 feet from ground zero, 29 kt Teapot-Apple 2, 5 May 1955.

Fatsia japonica shadow on electric pole, Meiji Bridge

DASA 1271

BIOLOGICAL EFFECTS OF BLAST

by

Clayton S. White, M.D.

Presented before
The Armed Forces Medical Symposium
Field Command, Defense Atomic Support
Agency, Sandia Base, Albuquerque, New Mexico
November 28, 1961

Technical Progress Report
on
Contract No. DA-49-146-XZ-055

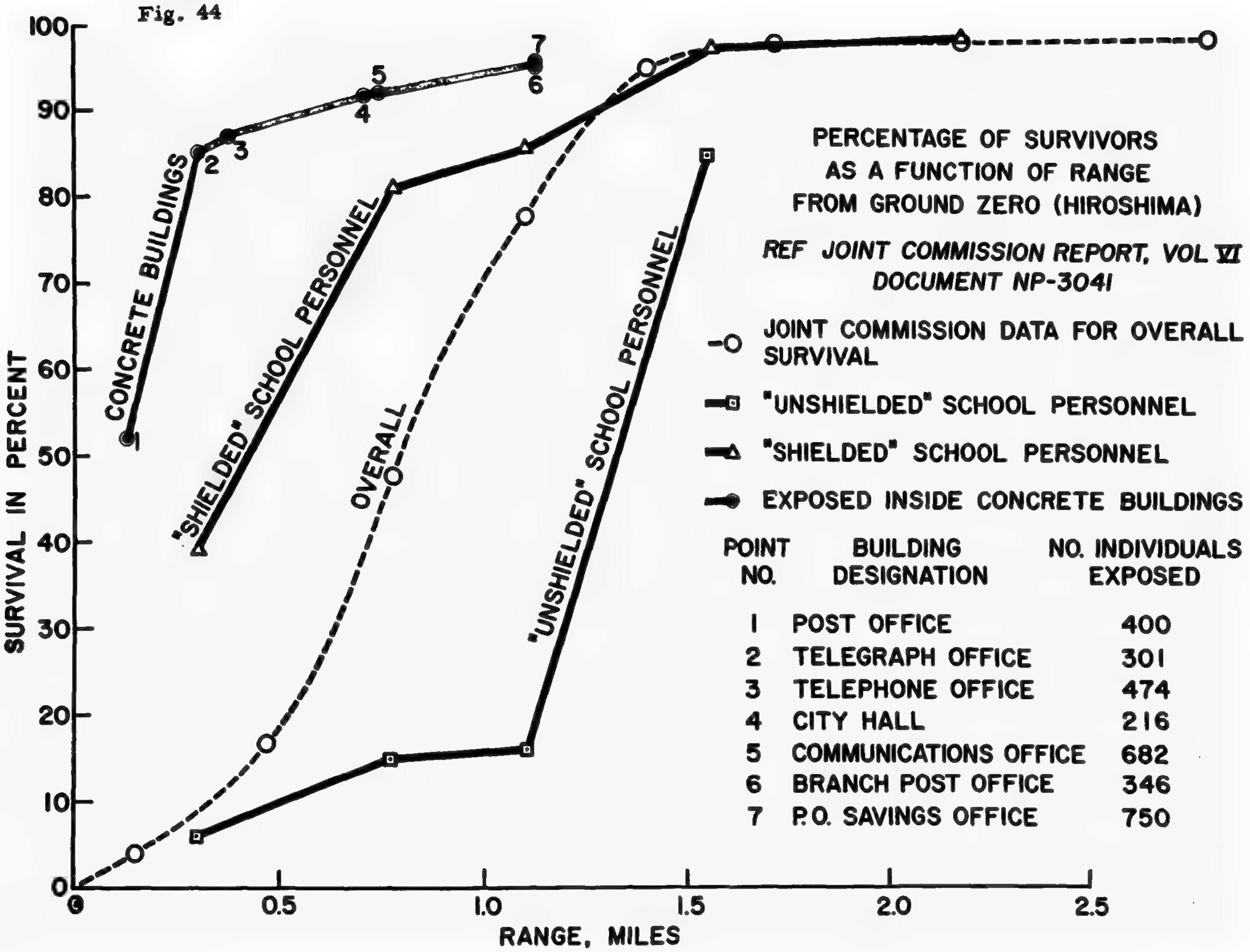
This work, an aspect of investigations dealing with the Biological Effects of Blast from Bombs, was supported by the Defense Atomic Support Agency of the Department of Defense.

Lovelace Foundation for Medical Education and Research

Albuquerque, New Mexico

December 1961

Fig. 44



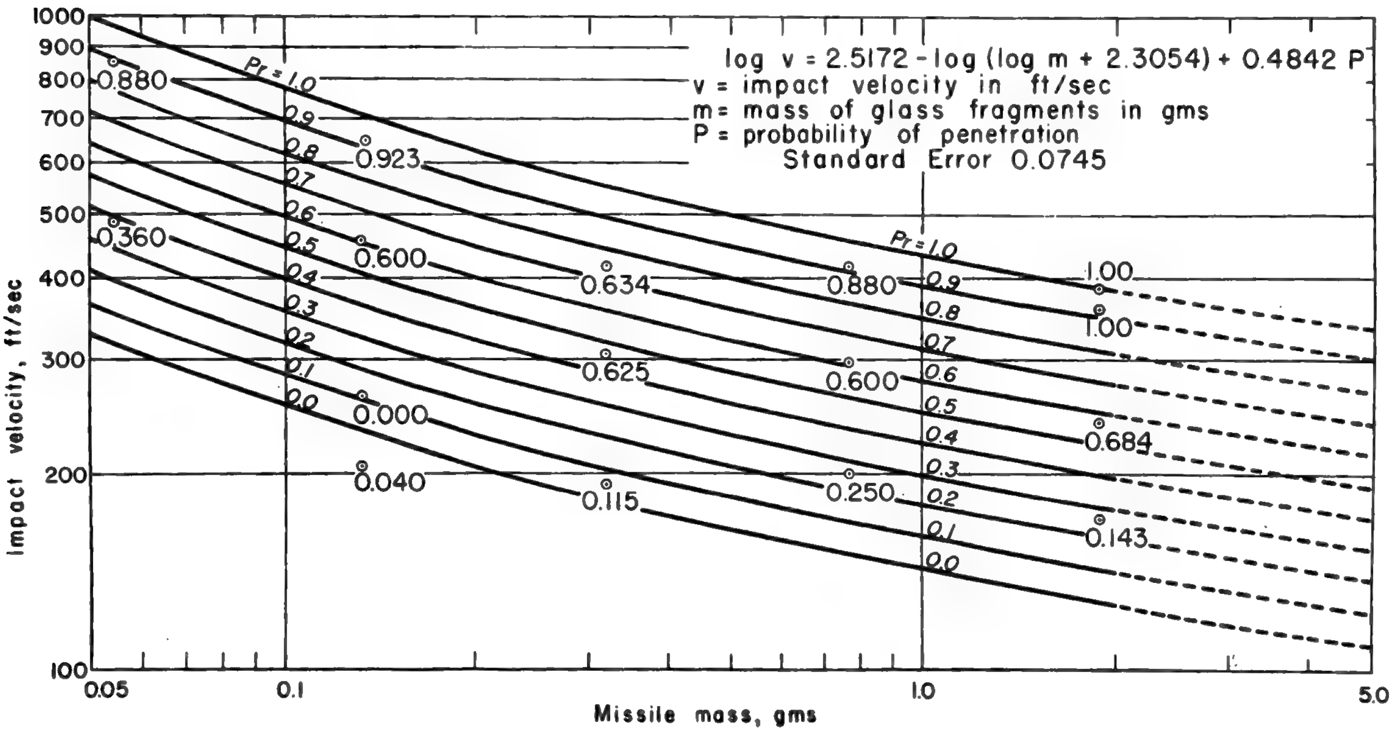
Oughterson, A. W., LeRoy, G. V., Liebow, A. A., Hammond, E. C., Barnett, H. L., Rosenbaum, J. D. and Schneider, B. A., "Medical Effects of Atomic Bombs — The Report of the Joint Commission for Investigation of the Effects of the Atomic Bomb in Japan," Vol. VI, AEC Technical Information Service, Oak Ridge, Tennessee, July 6, 1951.

TABLE 5

Comparative "Free"-field Effects Parameters at 50 Per Cent Survival Ranges for Hiroshima

Items of Interest	Conditions of Exposure			
	Concrete buildings	Inside schools	Mixed (average)	Outside schools
Range for 50% survival - mi	0.12	0.45	0.8	1.3
Estimated "free"-field effects at range for 50% survival				
Max side-on overpressure - psi	37	20	7.9	3.6
Max wind - mph	780	500	240	170
Thermal radiation - cal/cm^2	140	58	24	9
Initial ionizing radiation - rems	59,000	5800	480	15
Max displacement velocity at 10 ft of travel - ft/sec	10-gm glass fragment for a 20 kt burst		355	115

Probability of penetration of glass fragments into the abdomen Fig. 41



There are a number of simple lessons portrayed by these survival curves which actually relate human experience with a nuclear detonation. Let us consider some of the more important.

1. First, the 50 per cent survival ranges for the four curves from your right to left of 1.3, 0.8, 0.45 and 0.12 miles forcefully emphasizes the importance of the conditions of exposure.

2. The area of complete destruction at Hiroshima has been described as covering a circle of about 1.2-mile radius (4 square miles), a range at which 4-5 psi existed. At this range there was an over-all survival of near 90 per cent. It is apparent, therefore, that one must not confuse the area of complete destruction of houses (a physical concept) with "complete destruction" of people. Even in to near 0.2 mile, there was 5 per cent over-all survival. By way of emphasis, let it be clear that there was a marked difference between the ranges for physical and biological destruction at Hiroshima. The gloomy habit of confusing the two concepts is, I am afraid, as prevalent as it is unrealistic and, indeed, untrue.

3. The great good fortune of just being indoors and shielded against the most far-reaching effect, direct thermal radiation, is illustrated by the survival range of 0.45 mile for school personnel mostly inside compared with 1.3 miles for those mostly outside. This proved so even though the fact of being inside involved exposure to falling and flying debris, greater displacement potential and higher pressure reflections. Apparently, the latter hazards are relatively less than the dangers from direct thermal radiation.

4. The marked value of simply being inside concrete buildings is illustrated by the 50 per cent survival range of 0.12 mile.

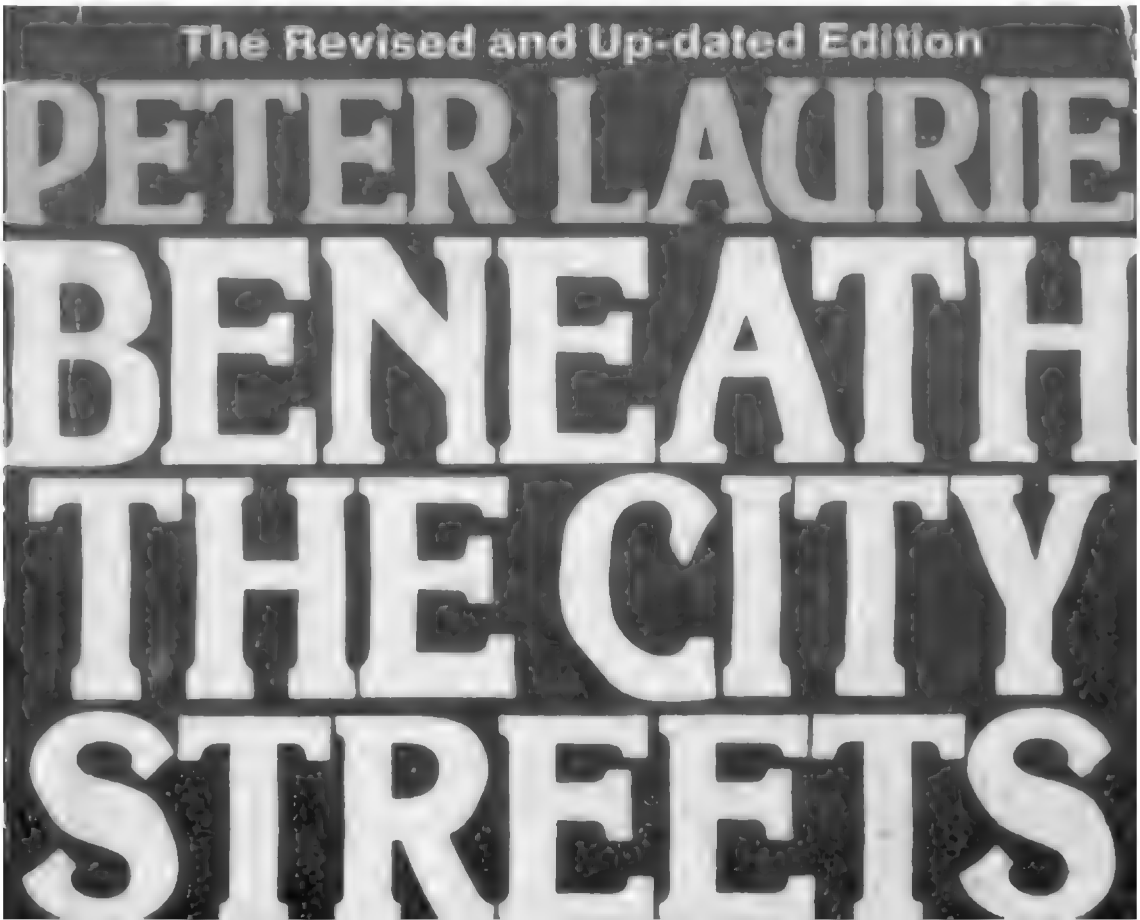
Houses as shelters

The chances of survival of people in such relatively fragile structures would seem to be small, but Second World War experience shows that they are better than one thinks. The main danger to people inside houses is collapse; but although the weapon that demolishes a house may vary enormously in size and range, the weight of a house remains the same, and in most cases the staircase is strong enough to support the debris that will fall on it. So people who shelter under the stairs – idiotic as this may sound for a precaution against nuclear weapons – will also be protected against heat flash and flying glass and have a good chance of surviving the almost complete destruction of their homes. Even at the 11 p.s.i. (0·8 kg/sq cm) line there should be no more than 11 per cent of people actually killed. . . .

In Düsseldorf in 1943, 30 per cent of the houses were destroyed, but only 0·01 per cent of people were killed or injured.

Peter Laurie

Revised and expanded edition published by
Granada Publishing Limited
in Panther Books 1979



AIR WAR AND EMOTIONAL STRESS

Psychological Studies of Bombing and Civilian Defense

Irving L. Janis
The RAND Corporation

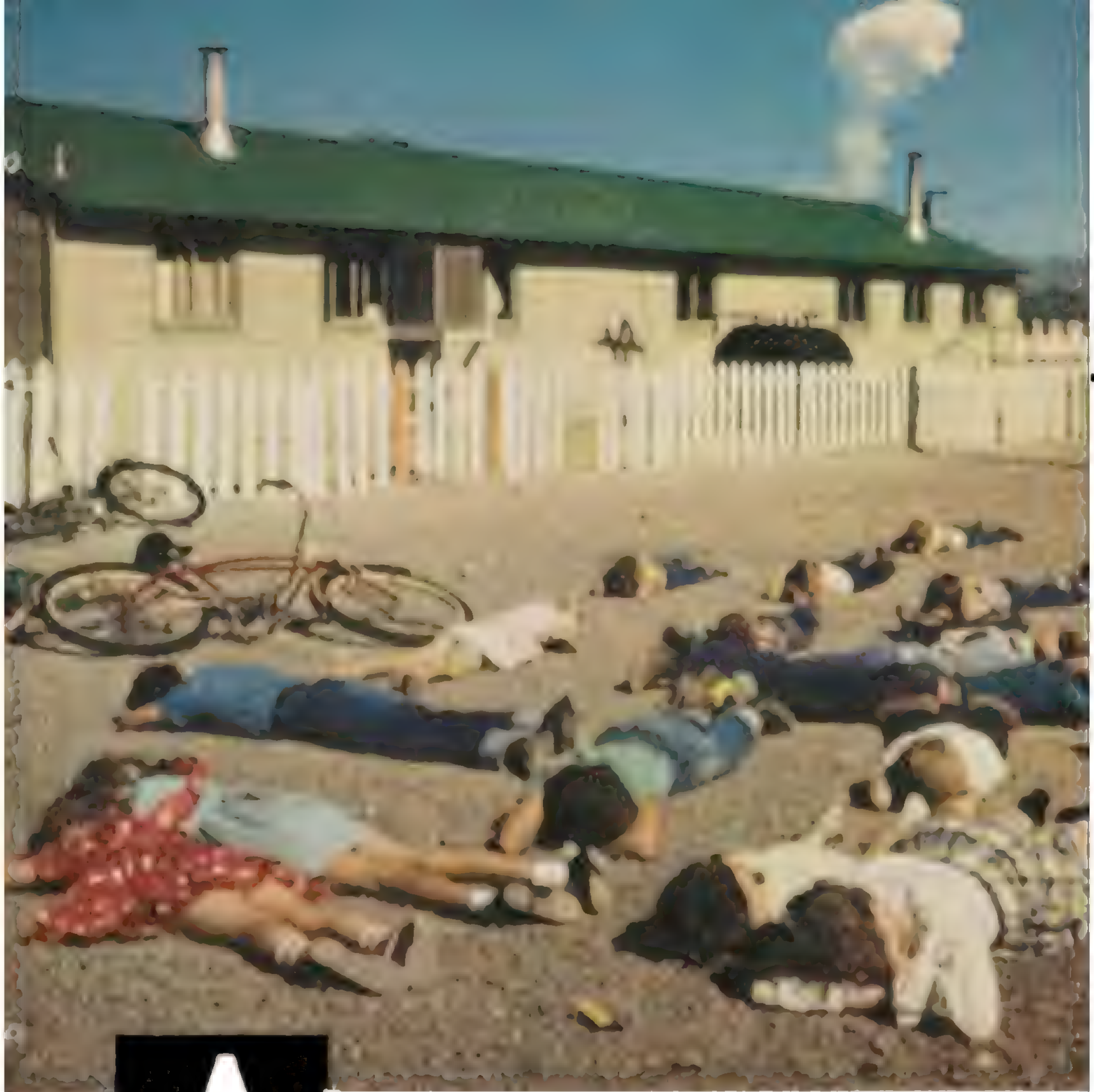
1951

Time from flash to blast = 4 sec at 1 mile:

A substantial proportion of the respondents in Hiroshima and Nagasaki reported having reacted immediately to the intense flash alone, as though it were a well-known danger signal, despite the fact that they were unaware of its significance at the time. A number of them said that they voluntarily ducked down or "hit the ground" as soon as the flash occurred and had already reached the prone position before the blast swept over them.

From the above discussion, it is apparent that some of the survivors immediately perceived the flash as a danger signal. It also appears that for those who were not located near the center there was an opportunity to take protective action that could reduce injuries from the secondary heat wave and from flying glass, falling debris, and other blast effects. It is noteworthy that some survivors evidently failed to make use of this opportunity, as is to be expected when there has been no prior preparation for it.

In a later chapter on the problems of civil defense, we shall have occasion to take account of these findings, since they suggest that casualties in an A-bomb attack might be reduced if the population has been well prepared in advance to react appropriately to the flash of the explosion.



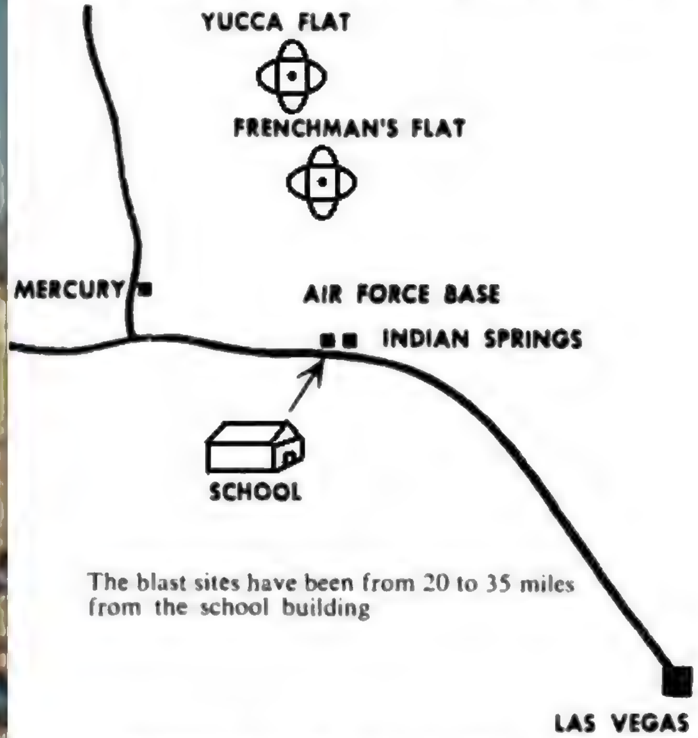
A IS FOR ATOM

By ROBERT CAHN

A dozen times, the awesome mushroom has risen in view of these youngsters, 25 miles from the Nevada test sites. Here's the story of our most atom-wise kids ▶

Collier's Weekly, June 21, 1952, pp. 15-17

Indian Springs (whose permanent population is 17) and adjacent air base are 42 miles from Las Vegas



The blast sites have been from 20 to 35 miles from the school building

SEVERAL months ago, the people of the nation learned with some interest that for the first time combat troops were to witness an atomic bomb test from close up. But to the youngsters at Indian Springs Public School, near Las Vegas, Nevada, such an experiment was old-hat. They already had seen, from less than 25 miles away, more atomic bomb blasts than anyone in the world except for the handful of nuclear scientists and technicians who set them off.

Starting last October, when the influx of atomic, military and construction personnel brought more than 200 families into the area, the Indian Springs school had become an unplanned experiment in the indoctrination of young children to atomic bombs.

"The children at this school, by their sheer proximity to the tests, are getting the same type of psychological indoctrination we are giving some of our combat troops," an Atomic Energy Commission spokesman commented recently. "If all the school children in the nation could witness an A-bomb blast, it would do much to destroy the fear and uncertainty which now exist."

Eighth-grader Dick Bower, thirteen, says he was once told at an atomic bomb drill in a southern California school that there was a possibility the whole earth could be blown up if enough such bombs were exploded. "I was really scared when we moved up here," Dick says, "but I have seen a couple of bombs go off now and it's just ordinary."

The Effects of

Nuclear Weapons

SAMUEL GLASSTONE

Editor

Revised Edition
Reprinted February 1964

Prepared by the

UNITED STATES DEPARTMENT OF DEFENSE

Published by the

UNITED STATES ATOMIC ENERGY COMMISSION

April 1962

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price $3.00 (paper bound)

Foreword

This book is a revision of "The Effects of Nuclear Weapons" which was issued in 1957. It was prepared by the Defense Atomic Support Agency of the Department of Defense in coordination with other cognizant governmental agencies and was published by the U.S. Atomic Energy Commission. Although the complex nature of nuclear weapons effects does not always allow exact evaluation, the conclusions reached herein represent the combined judgment of a number of the most competent scientists working on the problem.

There is a need for widespread public understanding of the best information available on the effects of nuclear weapons. The purpose of this book is to present as accurately as possible, within the limits of national security, a comprehensive summary of this information.

Secretary of Defense

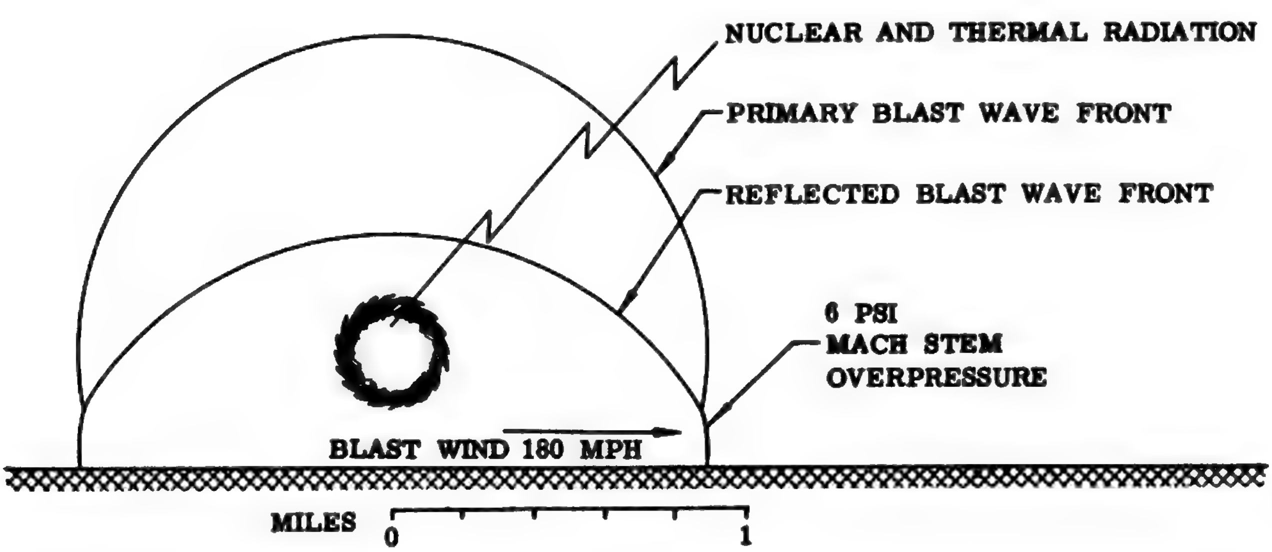
Chairman
Atomic Energy Commission

S. Glasstone, Effects of Nuclear Weapons, 1962:

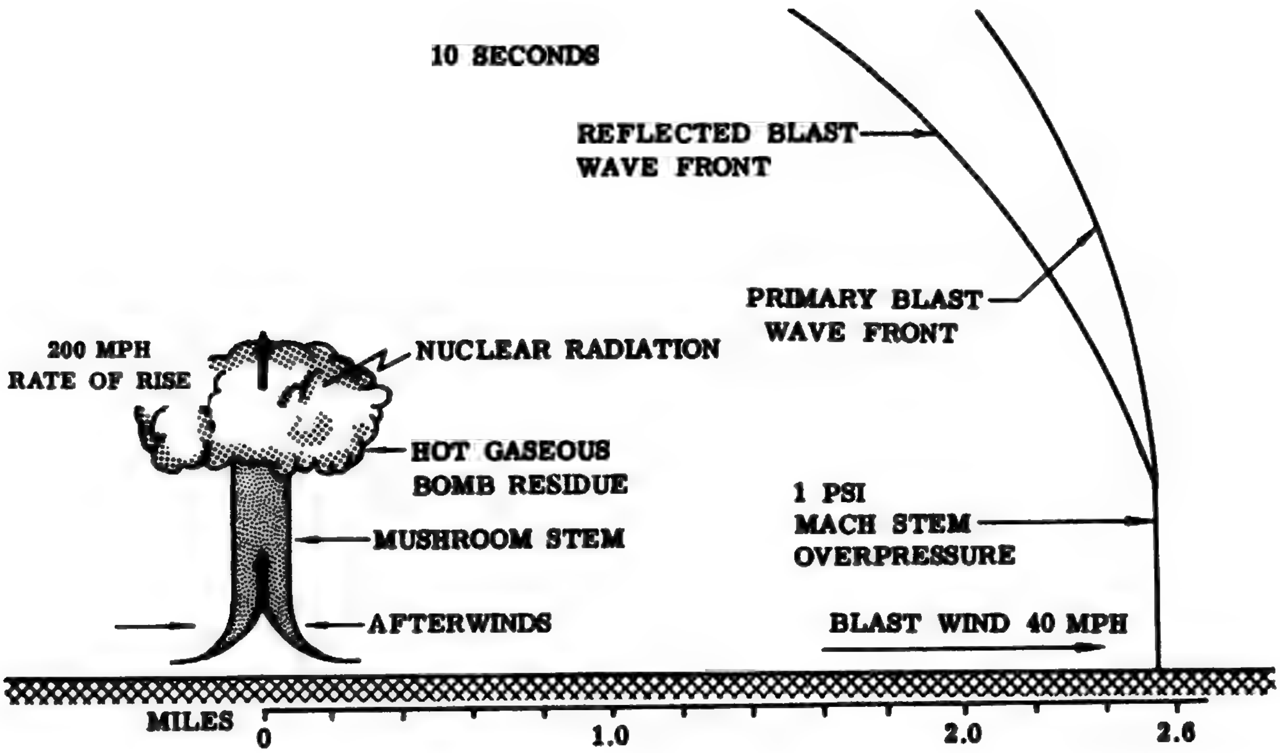
Explosion yield	*Height of burst (feet)*	*Time after detonation (seconds)*	*Distance from ground zero (miles)*	*Height of stem (feet)*
20 kilotons	1, 760	3	0. 87	185
1 megaton	6, 500	11	3. 2	680

20 KILOTON AIR BURST

3 SECONDS



10 SECONDS



At 10 seconds after a 20-kiloton explosion at an altitude of 1,760 feet the Mach front is over 2½ miles from ground zero, and 37 seconds after a 1-megaton detonation at 6,500 feet, it is nearly 9½ miles from ground zero. The overpressure at the front is roughly 1 pound per square inch, in both cases, and the wind velocity behind the front is 40 miles per hour.

12.11 In Japan, where little evasive action was taken, the survival probability depended upon whether the individual was outdoors or inside a building and, in the latter case, upon the type of structure. At distances between 0.3 and 0.4 mile (530 and 700 yards) from ground zero in Hiroshima the average survival rate, for at least 20 days after the nuclear explosion, was less than 20 percent. Yet in two reinforced-concrete office buildings, at these distances, almost 90 percent of the nearly 800 occupants survived more than 20 days, although some died later from radiation injury.

These facts bring out clearly the greatly improved chances of survival from a nuclear explosion that could result from the adoption of suitable warning and protective measures.

TABLE 12.29—ARRIVAL TIME FOR PEAK OVERPRESSURE

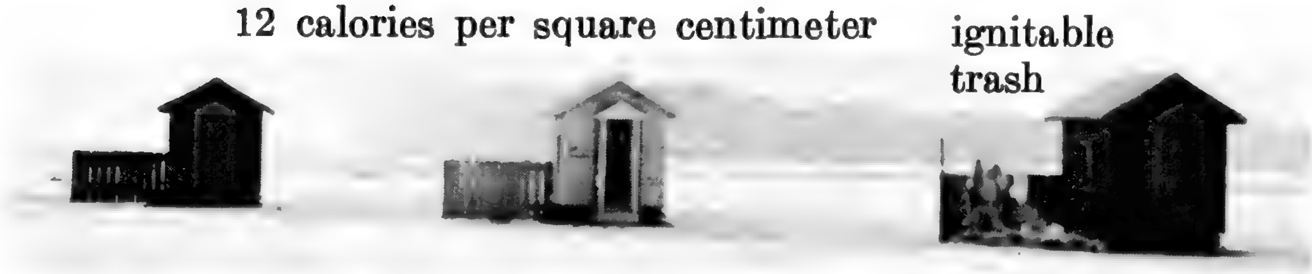
Distance (miles)	*Explosion yield*				
	1 KT	*10 KT*	*100 KT*	*1 MT*	*10 MT*
	(Time in seconds)				
1	4. 3	3. 6	3. 7	2. 5	1. 5
2	9	8. 1	7. 4	6. 5	5. 0

12.35. The major part of the thermal radiation travels in straight lines, and so any opaque object interposed between the fireball and the exposed skin will give some protection. This is true even if the object is subsequently destroyed by the blast, since the main thermal radiation pulse is over before the arrival of the blast wave.

12.36 At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, as described in § 12.30, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point.

12. 72 Because of its particulate nature, fallout will tend to collect on horizontal surfaces, e.g., roofs, streets, tops of vehicles, and the ground. In the preliminary decontamination, therefore, the main effort should be directed toward cleaning such surfaces. The simplest way of achieving this is by water washing, if an adequate supply of water is available. The addition of a commercial wetting agent (detergent) will make the washing more efficient. The radioactive material is thus tranferred to storm sewers where it is less of a hazard.

Nevada in 1953.



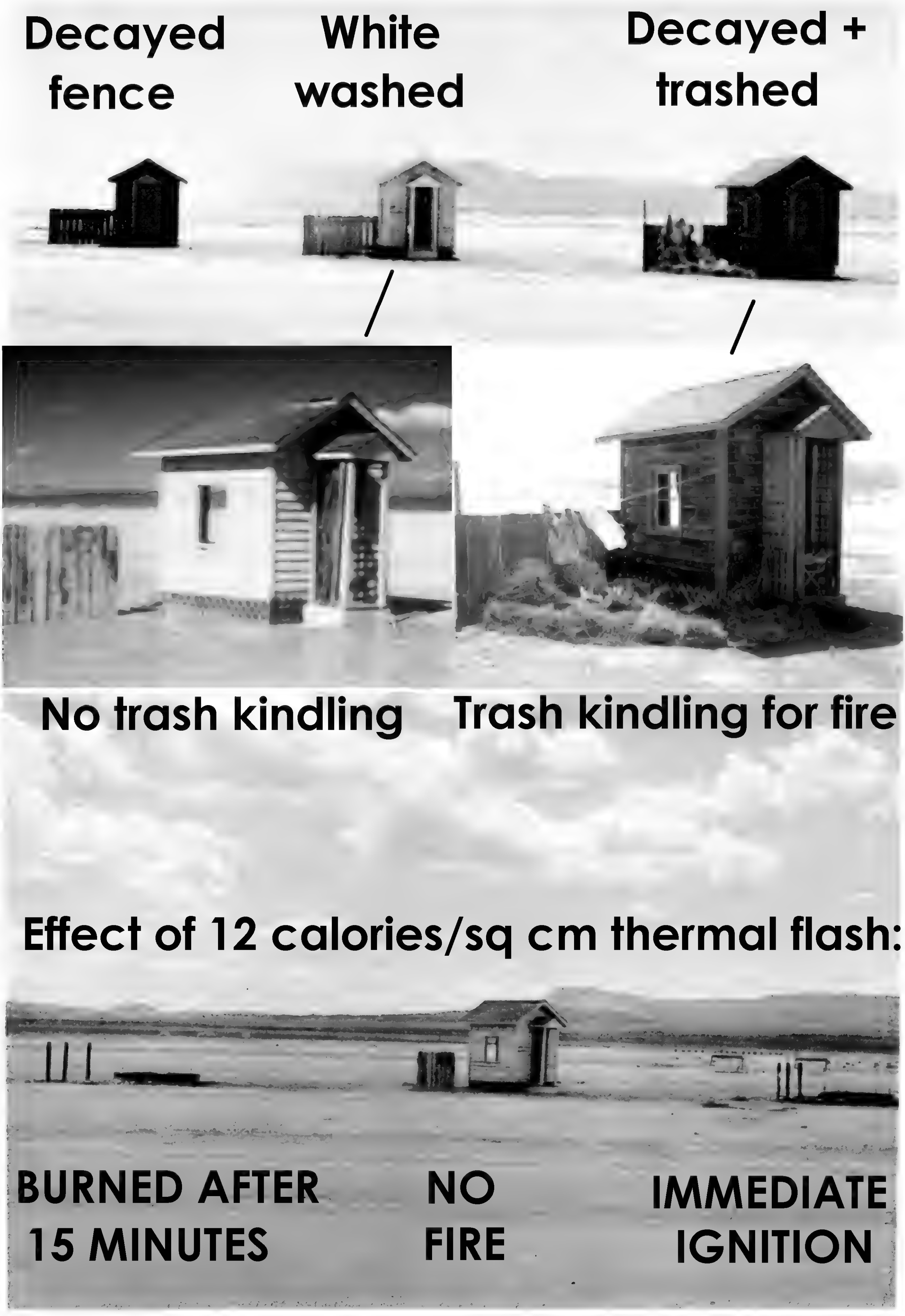
before exposure to a nuclear explosion

after exposure to a nuclear explosion

7.59 The value of fire-resistive furnishing in decreasing the number of ignition points was also demonstrated in the tests. Two identical, sturdily constructed houses, each having a window 4 feet by 6 feet facing the point of burst, were erected where the thermal radiation exposure was 17 calories per square centimeter. One of the houses contained rayon drapery, cotton rugs, and clothing, and, as was expected, it burst into flame immediately after the explosion and burned completely. In the other house, the draperies were of vinyl plastic, and rugs and clothing were made of wool. Although much ignition occurred, the recovery party, entering an hour after the explosion, was able to extinguish the fires.

7.76 It should be noted that the fire storm is by no means a special characteristic of nuclear weapons. Similar fire storms have been reported as accompanying large forest fires in the United States, and especially after incendiary bomb attacks in both Germany and Japan during World War II. The high winds are produced largely by the updraft of the heated air over an extensive burning area. They are thus the equivalent, on a very large scale, of the draft of a chimney under which a fire is burning. Because of limited experience, the conditions for the development of fire storms in cities are not well known. It appears, however, that some, although not necessarily all, of the essential requirements are the following: (1) thousands of nearly simultaneous ignitions over an area of at least a square mile, (2) heavy building density, e.g., more than 20 percent of the area is covered by buildings, and (3) little or no ground wind. Based on these criteria, only certain sections—usually the older and slum areas—of a very few cities in the United States would be susceptible to fire storm development.

Weapon test report WT-775, Project 8.11b, ENCORE nuclear test, Nevada, 1953:



6' x 6' wood frame houses

CONFIDENTIAL

WT-774

Copy No. 186 A

Operation UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS

March - June 1953

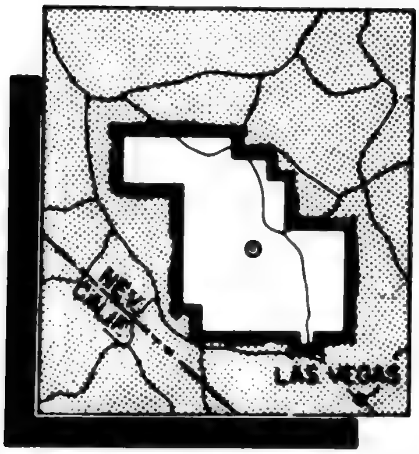
Project 8.11a

INCENDIARY EFFECTS ON BUILDING AND INTERIOR KINDLING FUELS

(ENCORE EFFECT REPORT)

27 kt at 2,423 feet altitude, 19% humidity

(DASA-1251) (Note: cities humidity is ~50-80%)



RESTRICTED DATA

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HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS PROJECT
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

CONFIDENTIAL

Weapon test report WT-774, Project 8.11a, Incendiary effects on buildings and interior kindling fuels

ENCORE test, Nevada, 1953
10' x 12' wooden houses with 4' x 6' windows
17 calories/sq. cm thermal flash

Immediate room flashover during thermal pulse
("Encore effect") in inflammables-filled house
while fire-resistant fabrics in other house survived!

LEFT HOUSE: fire-resistant furnishings
(woolen rugs and clothes, vinyl plastic draperies)

RIGHT HOUSE: non-fire resistant furnishings
plus inflammable magazines and newspapers

Smouldering armchair extinguished 1 hour after detonation, when recovery party arrived at house

---

-17-

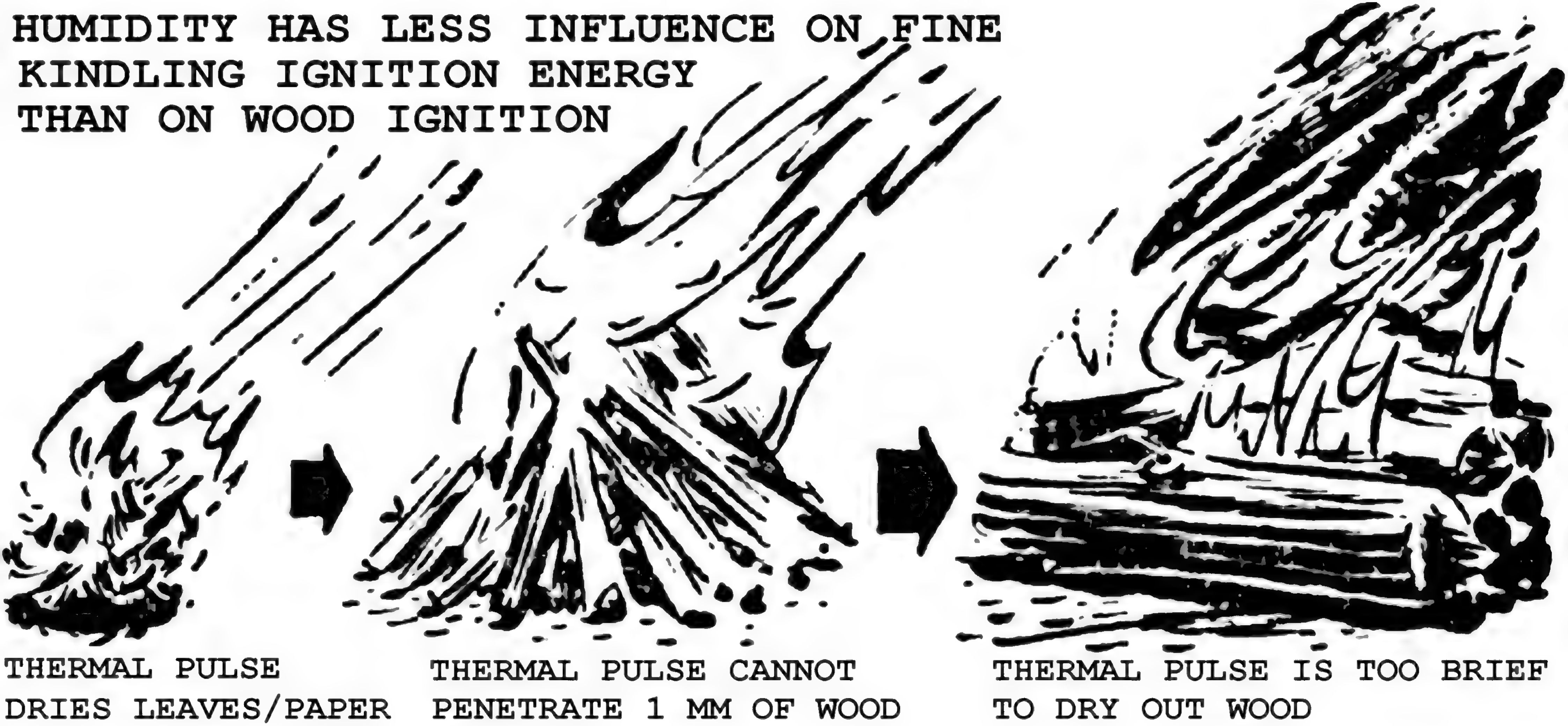
We have all had the frustrating experience of trying to light a fire with green, moist, or wet wood. Just as wet wood can't be easily induced to burn, so thick combustibles are not easily ignited. Even a dry two-by-four burns reluctantly and stops burning when taken out of the fire. It is a different matter with a shingle or a bunch of kindling! Density also plays a role, a heavier combustible being harder to ignite than lighter-weight material. Of course, the chemistry of the material to the degree that it influences kindling temperatures and flammability, is an important parameter. Modern plastics tend to smoke and boil - to ablate but not to ignite in sustained burning - while paper trash burns readily.

Just as most materials are not particularly sensitive to the sun's thermal radiation, and are not highly inflammable nor even ignitible, the surfaces exposed to the thermal intensity of a nuclear explosion are generally not given to sustained burning. Very intense heat loads may mar or melt surfaces, may char and burn surfaces while the heat is on, but may snuff out immediately afterward.

-18-

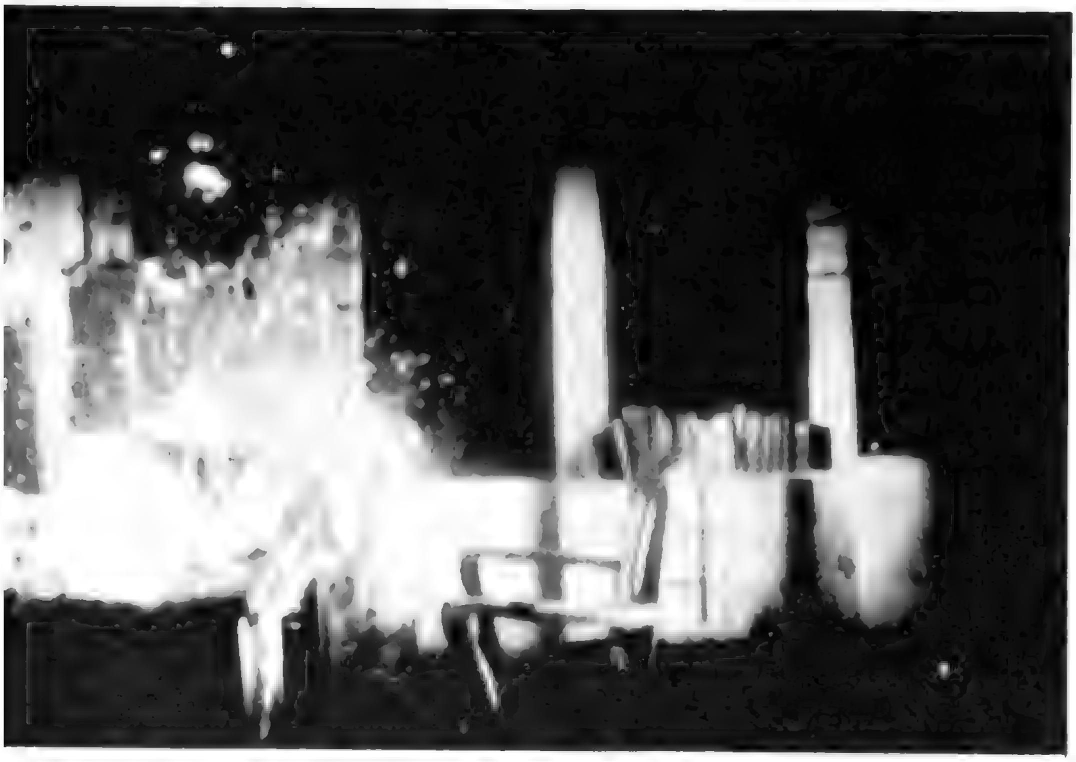
PRIMARY AND SECONDARY FIRES FROM NUCLEAR EXPLOSIONS

Although thermal radiation would start many fires in urban and in most suburban areas, such fires by themselves would seldom constitute a source of major destruction. Outside the region of extensive blast damage, fires in trash piles, in dry palm trunks, in roof shingles, in auto and household upholstery, drapes, or flammable stores are normally accessible and readily controllable. By the very fact that these fires start from material exposed to the incident light, they can be easily spotted and, in the absence of other distractions, can be quickly extinguished. Where the blast effects are severe and damage extensive, little effective fire fighting is likely.


HUMIDITY HAS LESS INFLUENCE ON FINE KINDLING IGNITION ENERGY THAN ON WOOD IGNITION
THERMAL PULSE DRIES LEAVES/PAPER
THERMAL PULSE CANNOT PENETRATE 1 MM OF WOOD
THERMAL PULSE IS TOO BRIEF TO DRY OUT WOOD

EFFECTS OF 1 PSI OVERPRESSURE ON IGNITIONS

From: Goodale, Effects of Air Blast on Urban Fires URS 7009–14 Dec. 1970 (AD 723 429)



Blast winds both cool burning material and upset flame convection system.

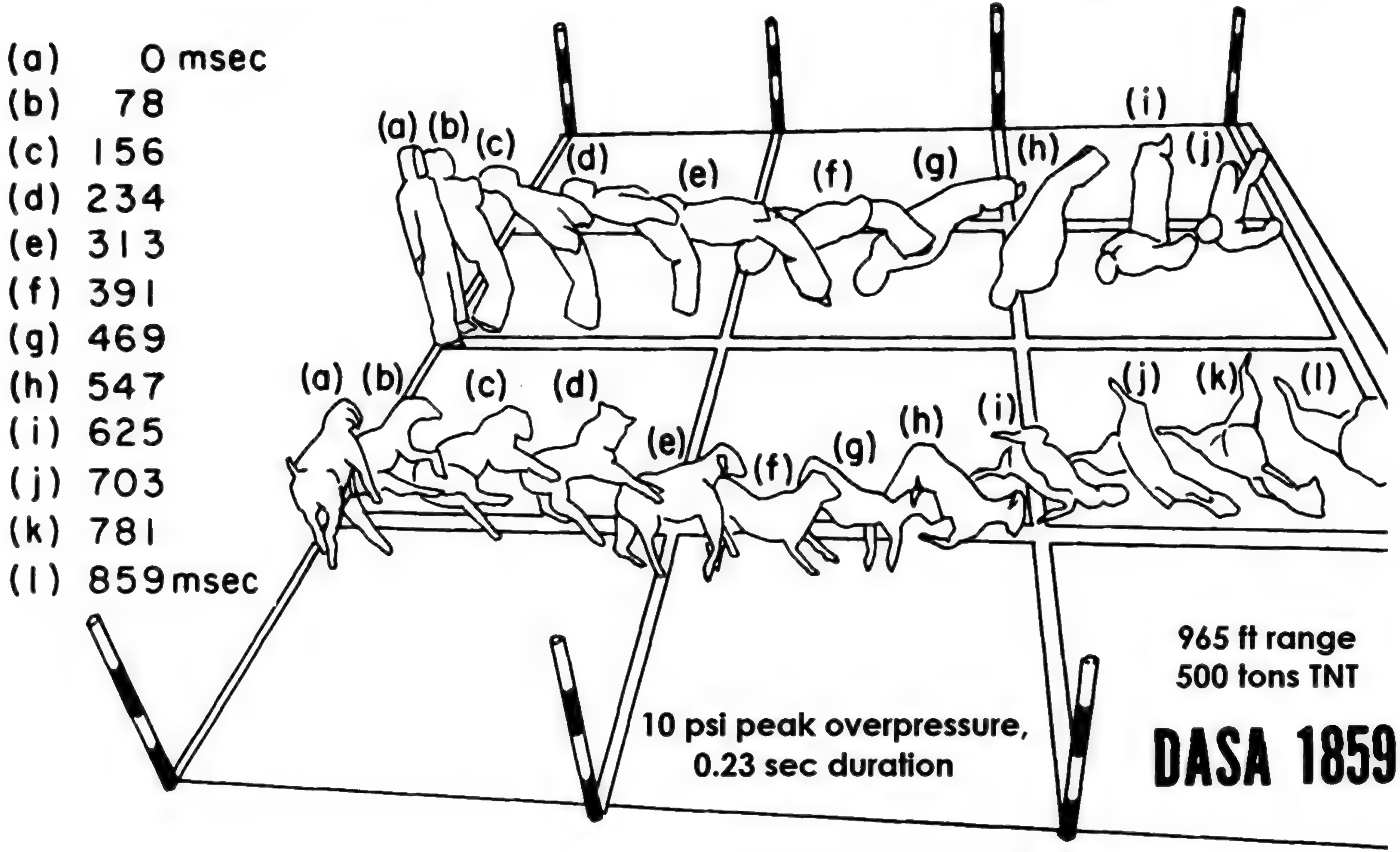
50% of burning curtains are extinguished by 1 psi overpressure

100% are put out by 2.5 psi. Note that burning LIQUIDS in high-wall trays are not put out by blast waves, but this is not relevant to city fires.

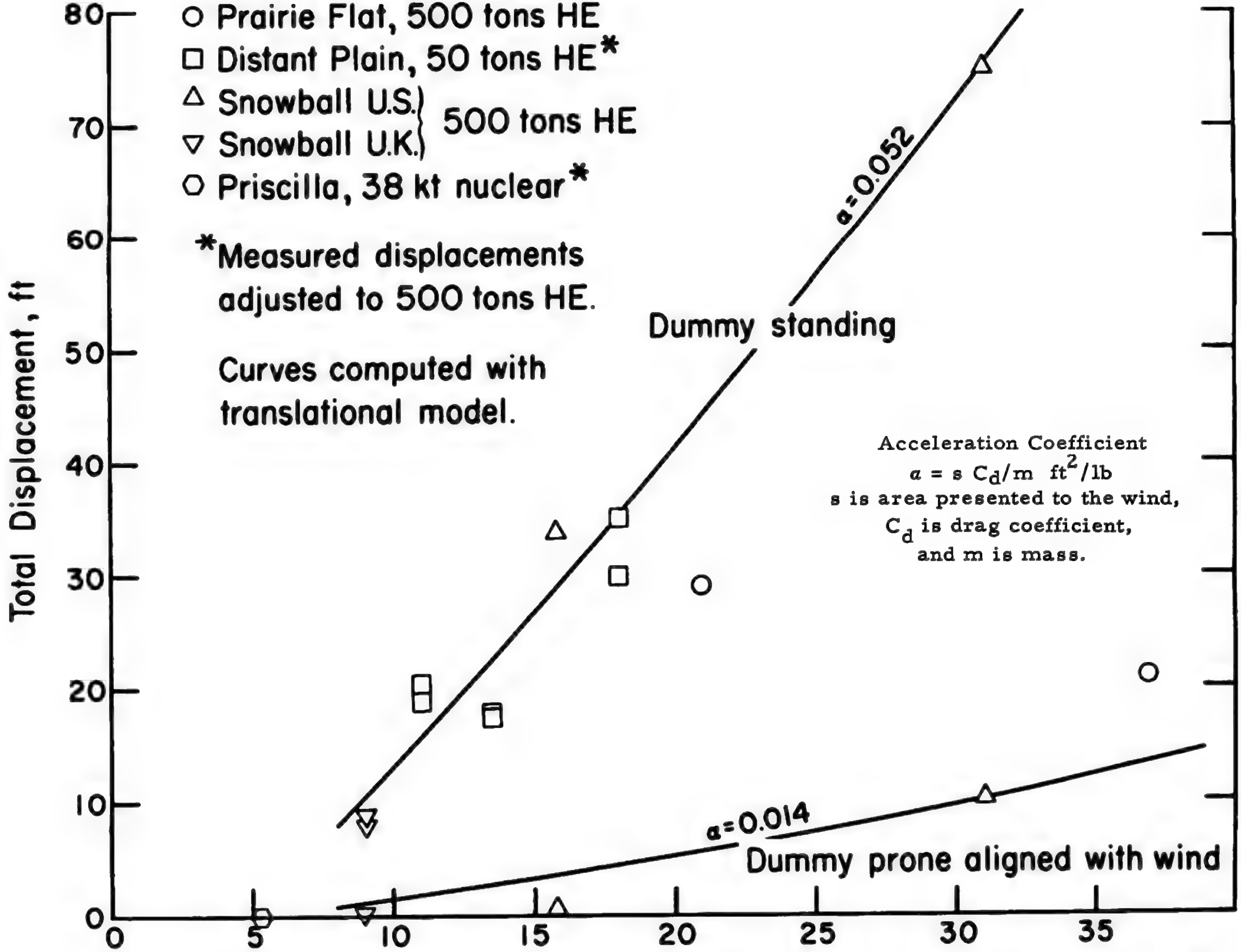
Burning beds can continue to smoulder until extinguished with water.

Operation SAILOR HAT, 0.5 kt shot CHARLIE, at Kahoolawe island, Hawaii, on 16 April 1965. The displacement effects to a standing observer at a peak overpressure of 6 psi (41 kPa) were simulated by using a realistic (fully articulated) dummy.

Operation Snowball, station 10SB, comparison of human dummy with standing goat (proxy) peak velocity of initially standing 165 lb dummy = 33.7 ft/sec with 20 ft total displacement (A U.K. dummy lying prone at 9 psi peak overpressure was unmoved in this test)

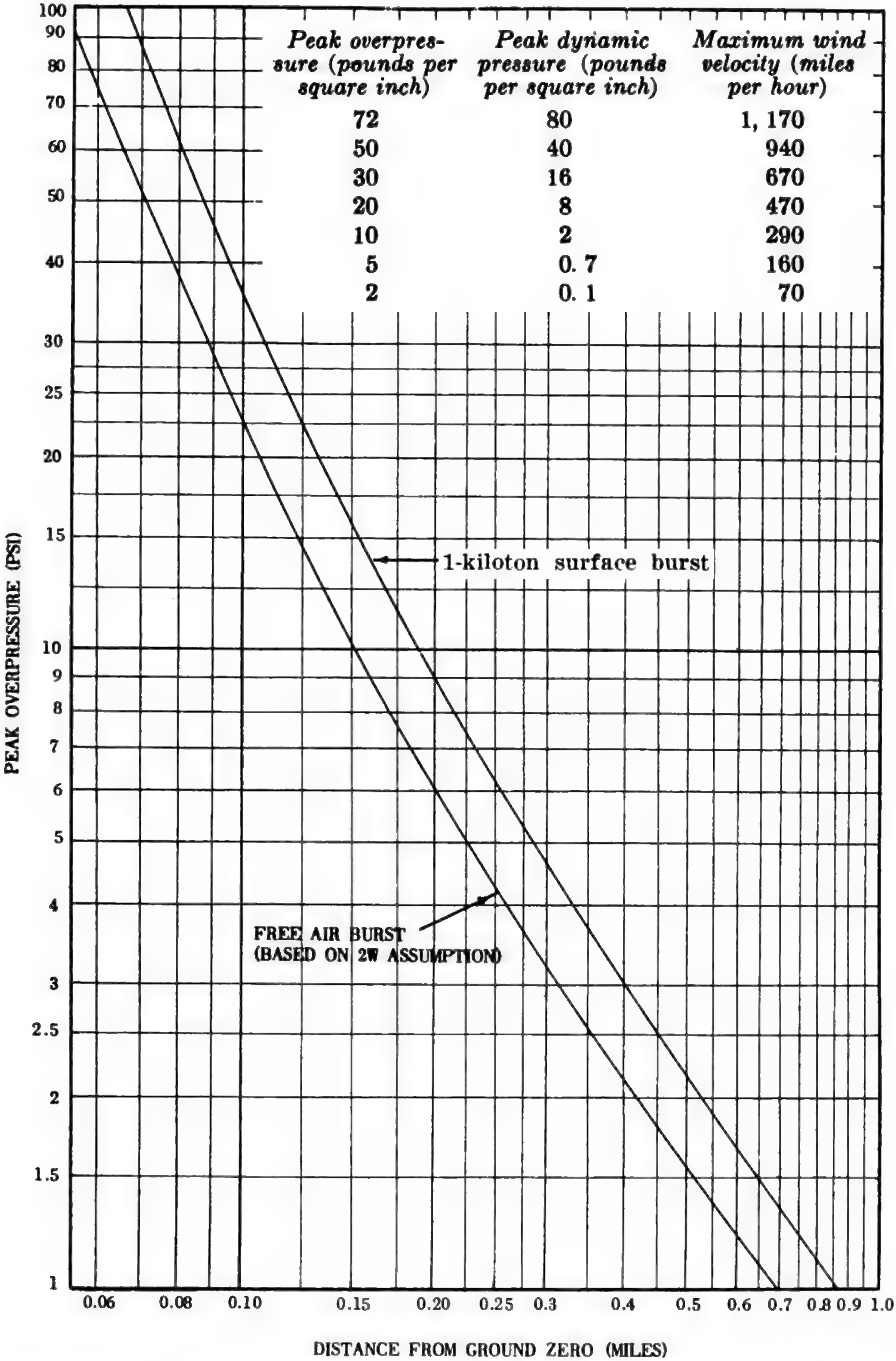


DASA 1859



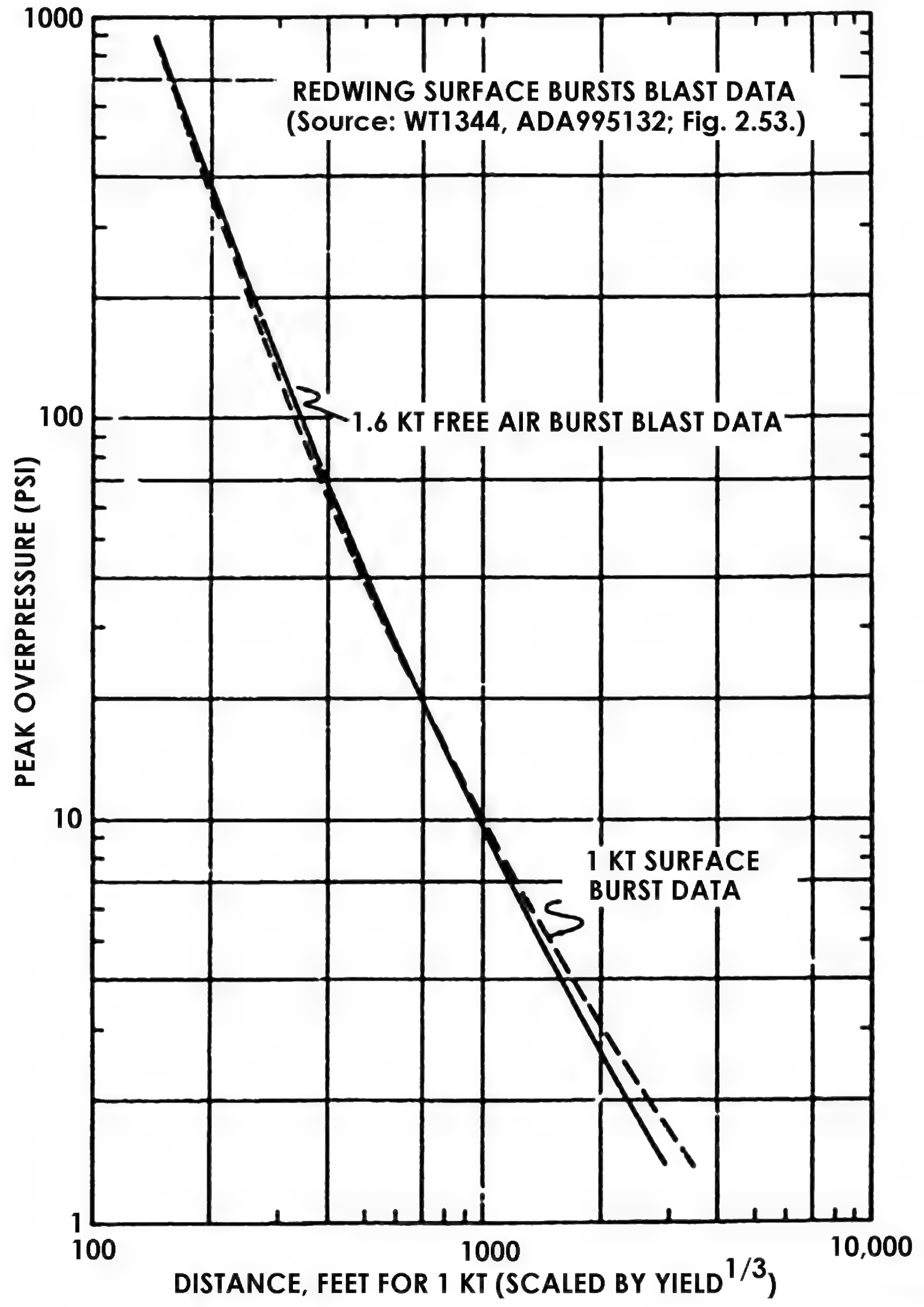
○ Prairie Flat, 500 tons HE
□ Distant Plain, 50 tons HE*
△ Snowball U.S.
▽ Snowball U.K.
500 tons HE
⬡ Priscilla, 38 kt nuclear*
*Measured displacements adjusted to 500 tons HE.
Curves computed with translational model.
Dummy standing
α=0.052
Acceleration Coefficient
α = s Cd/m ft2/lb
s is area presented to the wind,
Cd is drag coefficient,
and m is mass.
α=0.014
Dummy prone aligned with wind
Total Displacement, ft
Peak Overpressure, psi
0
5
10
15
20
25
30
35
10
20
30
40
50
60
70
80

DASA 2710



Peak overpressure (pounds per square inch)	Peak dynamic pressure (pounds per square inch)	Maximum wind velocity (miles per hour)
72	80	1, 170
50	40	940
30	16	670
20	8	470
10	2	290
5	0. 7	160
2	0. 1	70

Scaling. For yields other than 1 KT, the range to which a given overpressure extends scales as the cube root of the yield



REDWING SURFACE BURSTS BLAST DATA
(Source: WT1344, ADA995132; Fig. 2.53.)
1.6 KT FREE AIR BURST BLAST DATA
1 KT SURFACE
BURST DATA
PEAK OVERPRESSURE (PSI)
1000
100
10
1
100
1000
10,000
DISTANCE, FEET FOR 1 KT (SCALED BY YIELD$^{1/3}$)

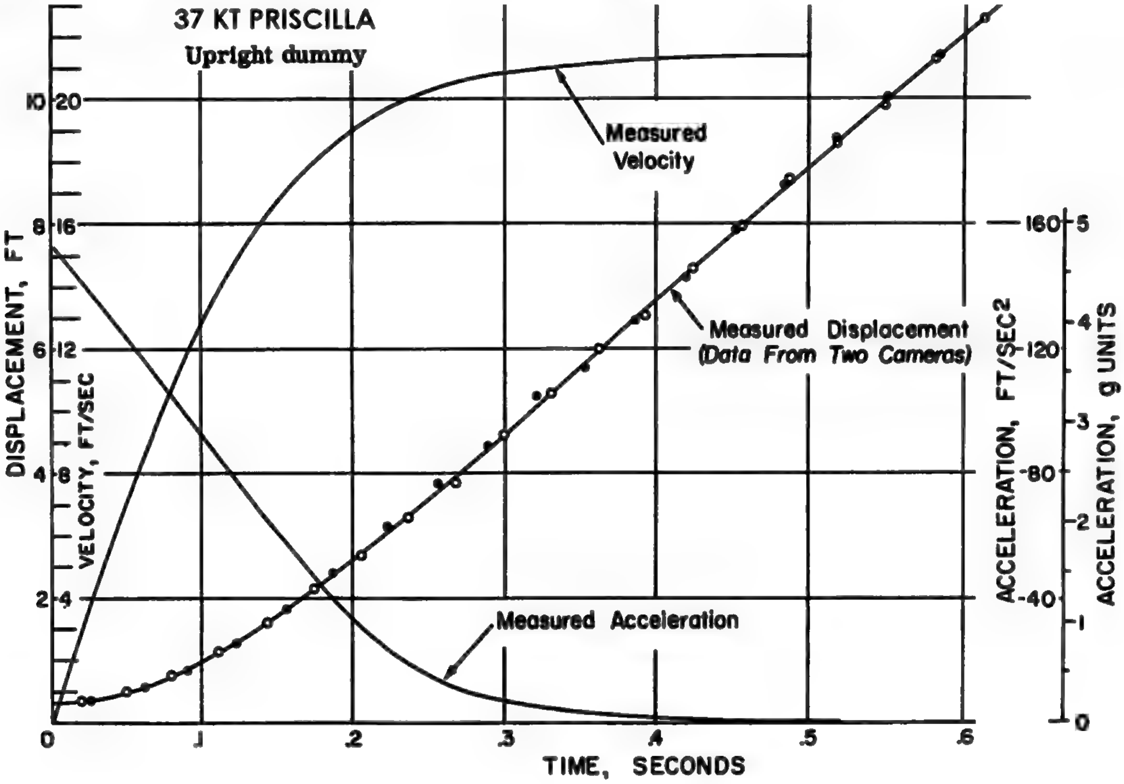
WT-1469
and
DASA-1777
AD638342

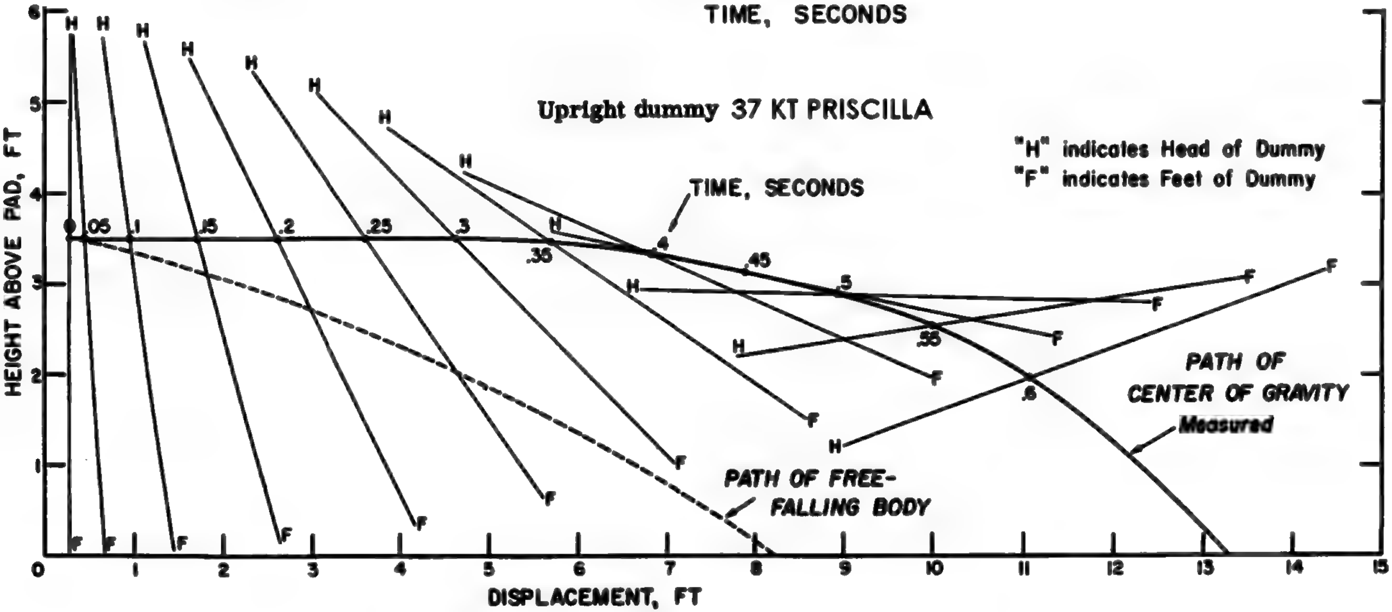
TEST (BOTH ON 700 FT TOWERS)	37 KT PRISCILLA	44 KT SMOKY	
GROUND RANGE	**5320 FT**	**3406 FT**	
Static pressure	5.3 psi	6.6 psi	PRECURSOR
Dynamic pressure	0.7 psi	15.8 psi	
Movement			
Prone dummy	0	124 ft	PRECURSOR
Upright dummy	21.9 ft	255.7 ft	
Velocity			
Prone dummy	0		
Upright dummy	21.4 ft/sec max. at 0.45 sec		

Prone dummy after 37 KT PRISCILLA

Upright dummy after 37 KT PRISCILLA

165 lb dummy lying prone at 5.3 psi overpressure from Priscilla was unmoved, but standing dummy was translated 13 ft in air and then rolled for 9 ft.





WT-1454

SMOKY 1957 PRECURSOR BLAST WAVEFORM

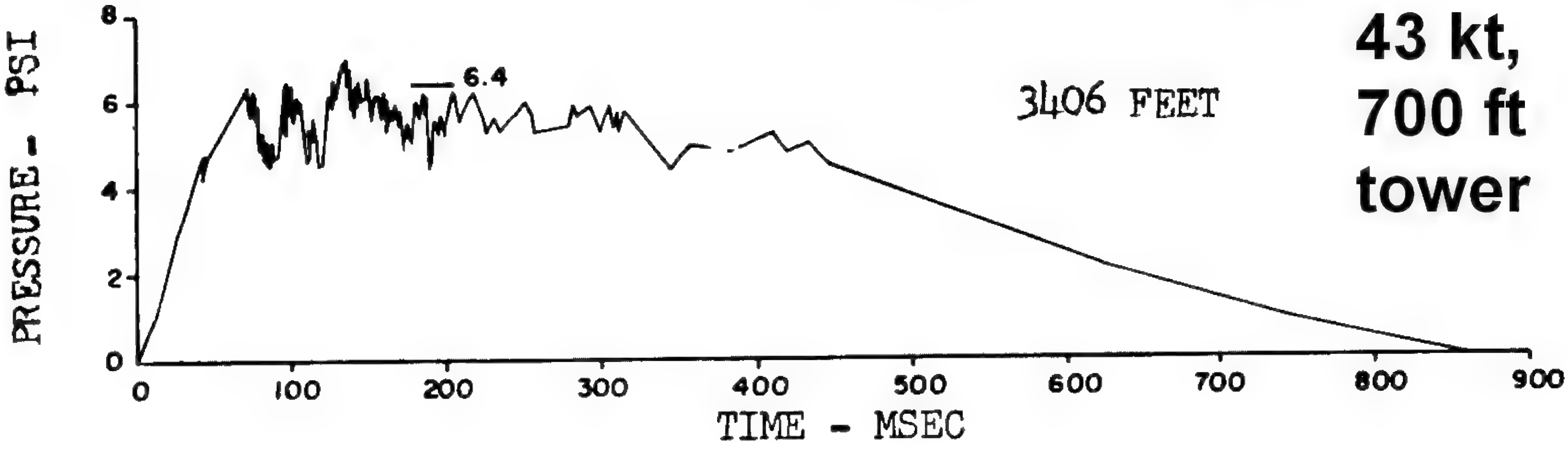
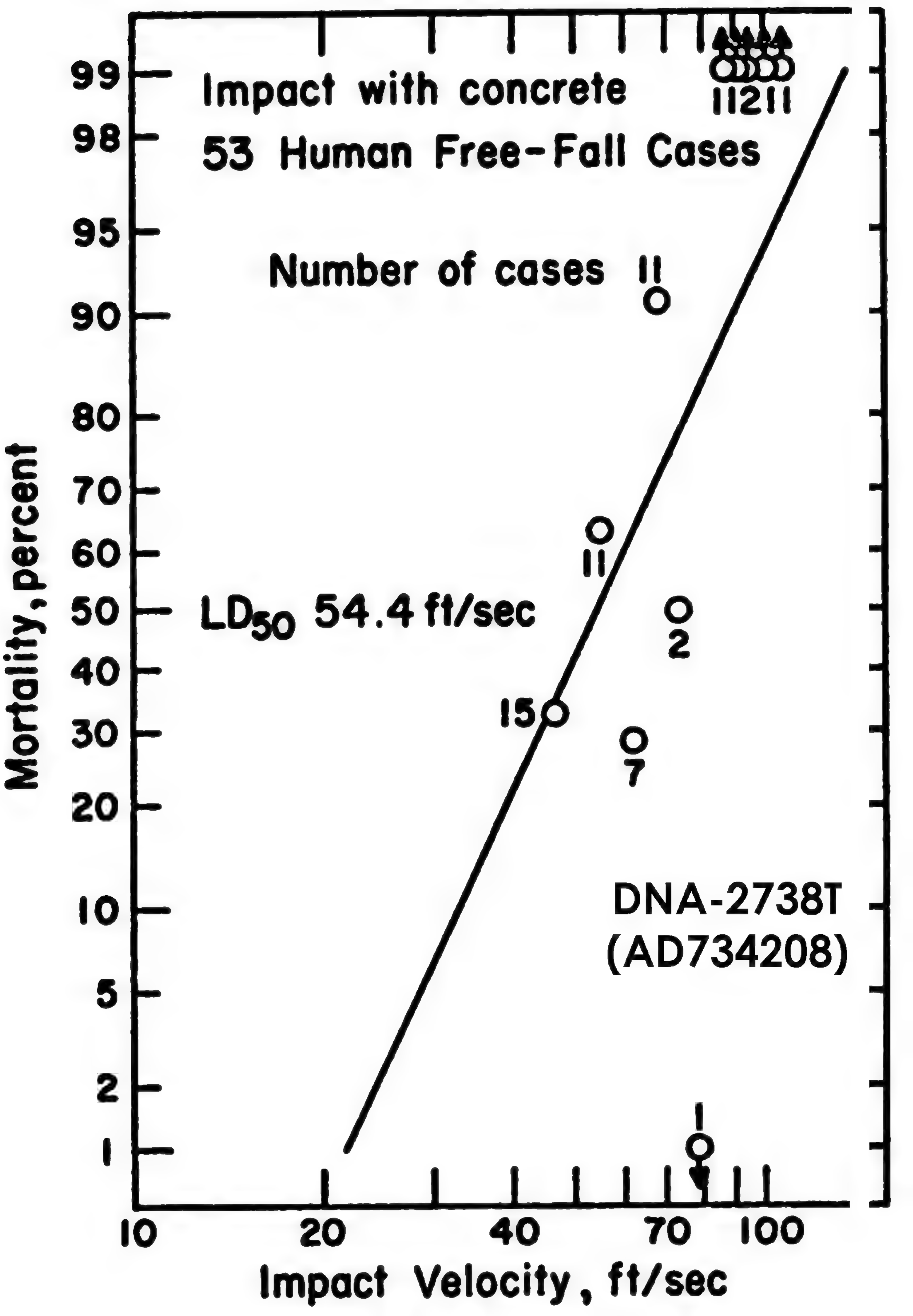
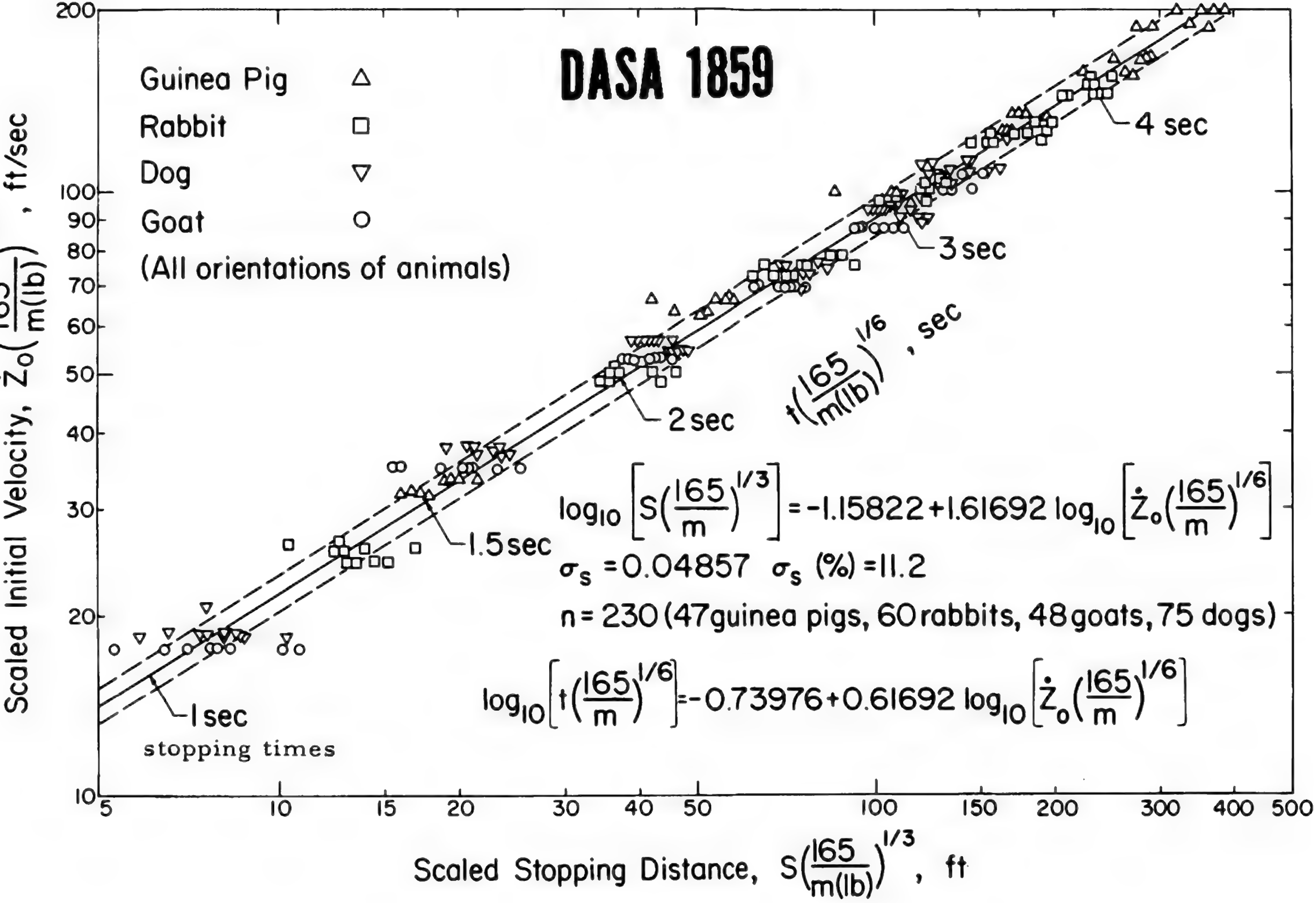
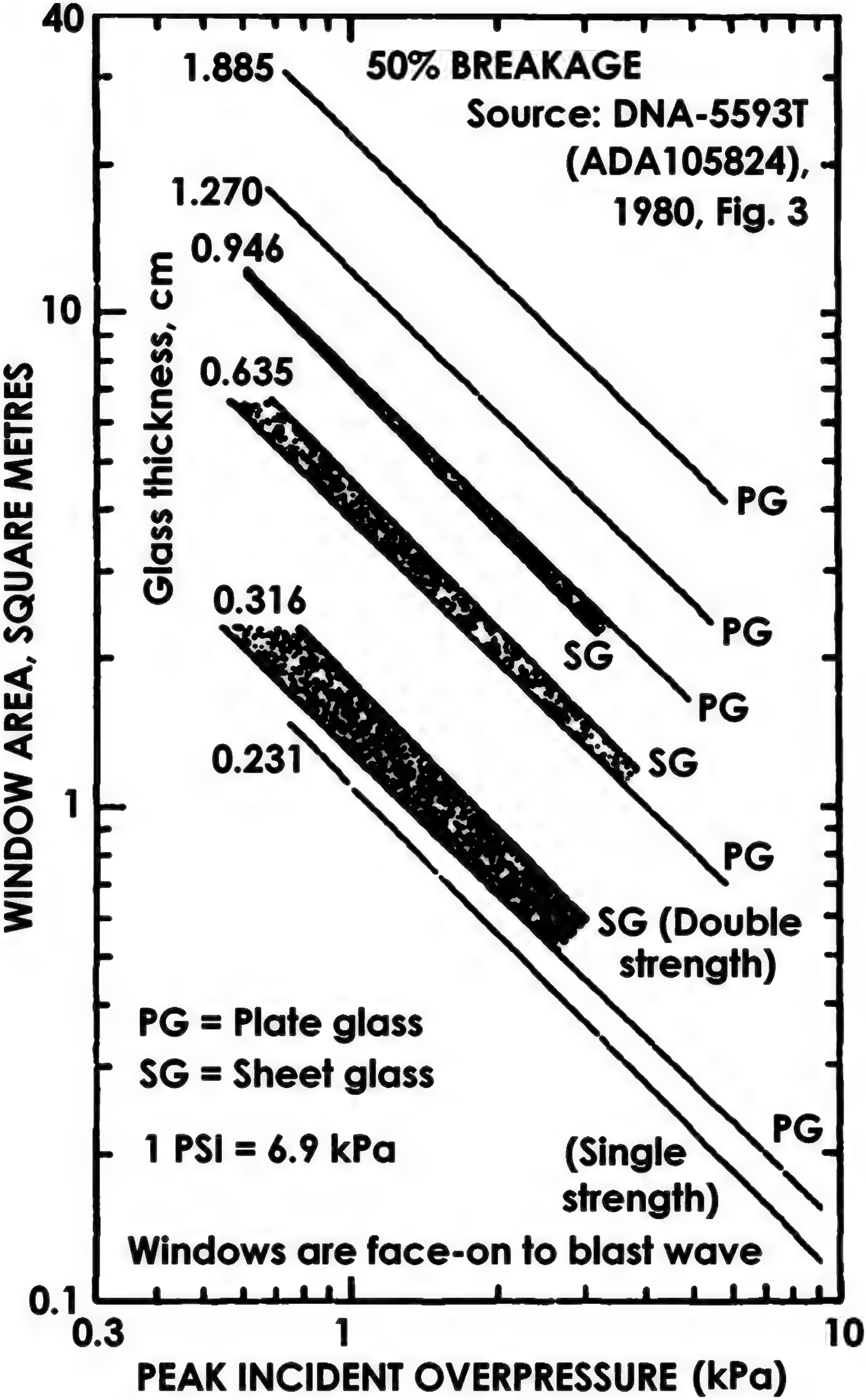


Fig. 3.109—Blast-line pressure-time; self-recording pressure gauge records.


Impact with concrete
53 Human Free-Fall Cases
Number of cases
LD50 54.4 ft/sec
DNA-2738T
(AD734208)
Mortality, percent
Impact Velocity, ft/sec
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
10
20
40
70
100
11
11
15
2
7
1
1
1
2
1
1


DASA 1859
Guinea Pig
Rabbit
Dog
Goat
(All orientations of animals)
1 sec
1.5 sec
2 sec
3 sec
4 sec
stopping times
$t\left(\frac{165}{m(lb)}\right)^{1/6}$, sec
$\log_{10}\left[S\left(\frac{165}{m}\right)^{1/3}\right] = -1.15822 + 1.61692 \log_{10}\left[\dot{Z}_o\left(\frac{165}{m}\right)^{1/6}\right]$
$\sigma_s = 0.04857 \quad \sigma_s\ (\%) = 11.2$
n = 230 (47 guinea pigs, 60 rabbits, 48 goats, 75 dogs)
$\log_{10}\left[t\left(\frac{165}{m}\right)^{1/6}\right] = -0.73976 + 0.61692 \log_{10}\left[\dot{Z}_o\left(\frac{165}{m}\right)^{1/6}\right]$
Scaled Initial Velocity, $\dot{Z}_o\left(\frac{165}{m(lb)}\right)^{1/6}$, ft/sec
Scaled Stopping Distance, $S\left(\frac{165}{m(lb)}\right)^{1/3}$, ft



50% BREAKAGE
Source: DNA-5593T (ADA105824), 1980, Fig. 3
Glass thickness, cm
1.885
1.270
0.946
0.635
0.316
0.231
PG
PG
SG
PG
SG
PG
SG (Double strength)
PG
(Single strength)
PG = Plate glass
SG = Sheet glass
1 PSI = 6.9 kPa
Windows are face-on to blast wave
WINDOW AREA, SQUARE METRES
40
10
1
0.1
0.3
1
10
PEAK INCIDENT OVERPRESSURE (kPa)

AECU-3350

UNITED STATES ATOMIC ENERGY COMMISSION

BIOLOGICAL EFFECTS OF BLAST FROM BOMBS. GLASS FRAGMENTS AS PENETRATING MISSILES AND SOME OF THE BIOLOGICAL IMPLICATIONS OF GLASS FRAGMENTED BY ATOMIC EXPLOSIONS

By
I. Gerald Bowen
Donald R. Richmond
Mead B. Wetherbe
Clayton S. White

Table 5.1 Statistical Parameters and Predicted Penetration Data for Missiles from Traps at Various Ranges from Ground Zero

30 kt TEAPOT-APPLE 2 nuclear test, 1955

Distance from Ground Zero, ft	4,700	5,500	10,500
Maximum overpressure, psi	5.0	3.8	1.9
Number of traps	6	2	5
Total number of glass missiles	2129	320	37
Geometric mean missiles mass, gms	0.133	0.580	1.25
Standard geometric deviation in mass	3.01	3.47	3.35
Geometric mean missile velocity, ft/sec	170	168	103
Standard geometric deviation in velocity	1.27	1.25	1.25
Per cent of total missiles expected to penetrate	3.9*	12.8*	0.4*
Average number of missiles per sq ft	100.9	45.5	2.1
Missiles per sq ft expected to penetrate	3.9*	5.3*	0.006*

*Computed from individual evaluation of each missile

AD A105824 **DNA 5593T**

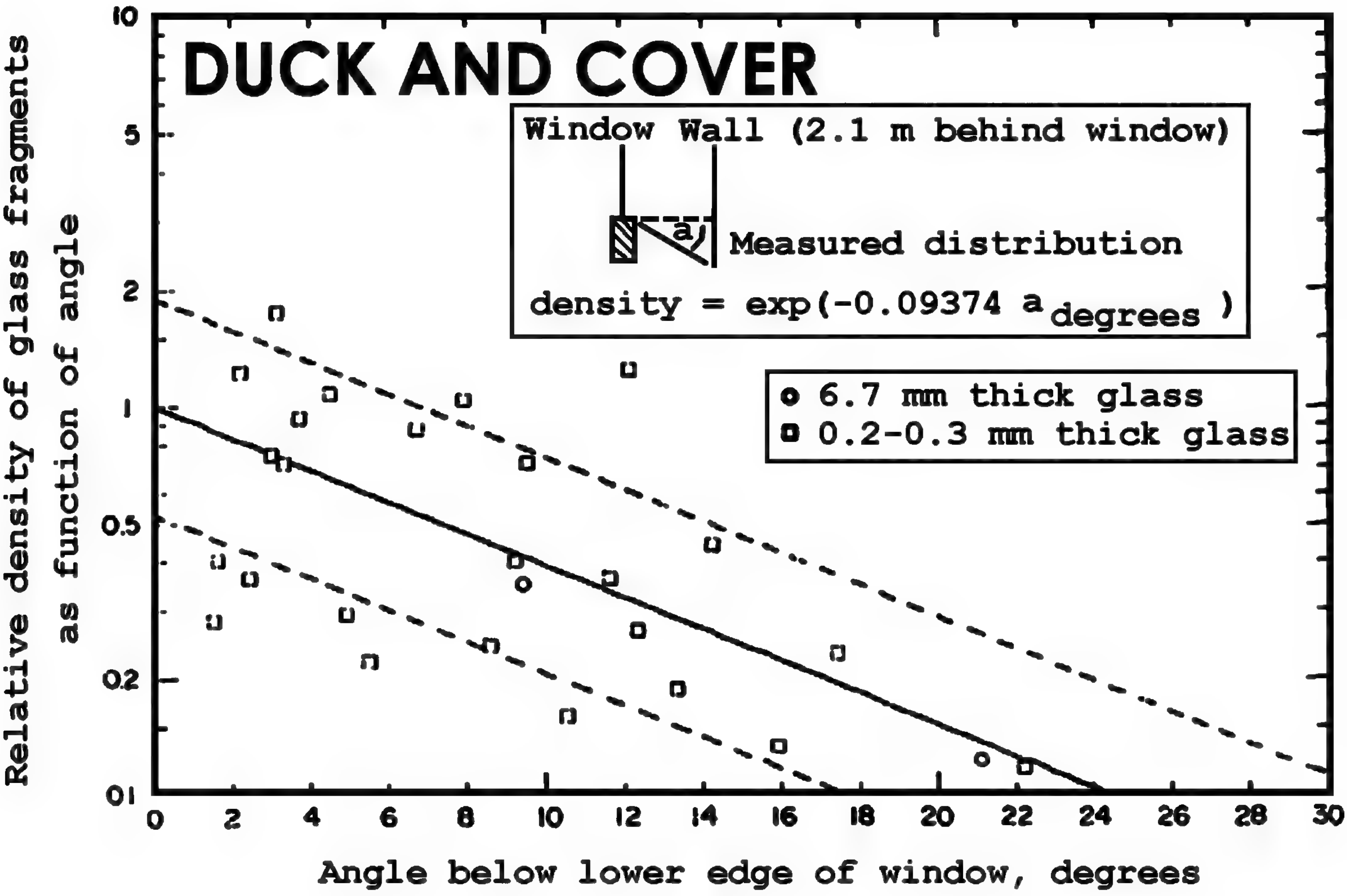
GLASS FRAGMENT HAZARD FROM WINDOWS BROKEN BY AIRBLAST

E. Royce Fletcher

Flying glass injured to 3.2 km in Hiroshima, 3.8 km in Nagasaki. 3.2 mm thick window glass fragments striking walls 2.1 m behind the windows in nuclear and high explosive tests gave:

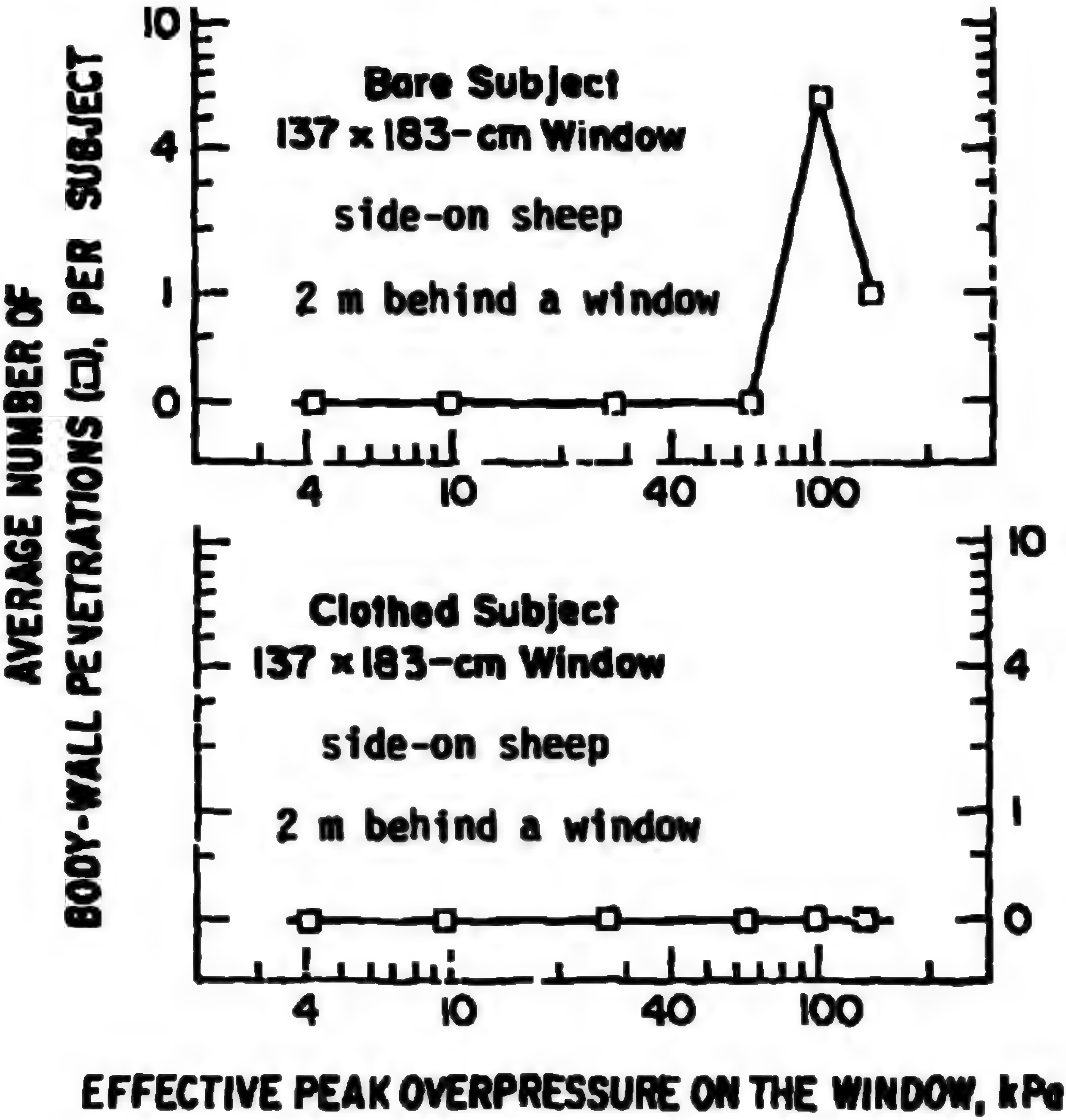
10 fragments/m^2 for 6.3 kPa (0.9 psi) overpressure
100 fragments/m^2 for 29 kPa (4.2 psi) overpressure
1,000 fragments/m^2 for 65 kPa (9.4 psi) overpressure

Figure 10



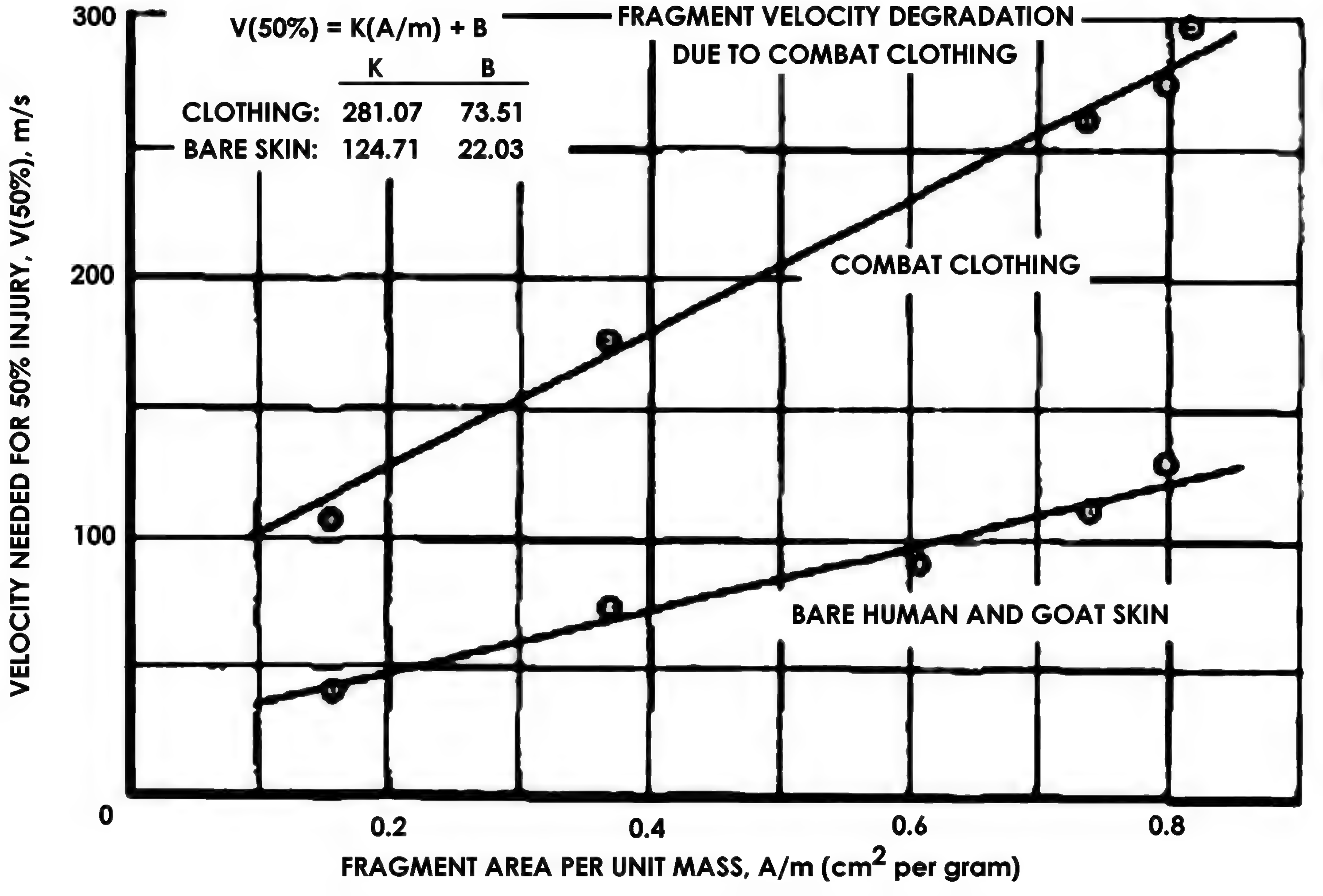
Glass-fragment injuries

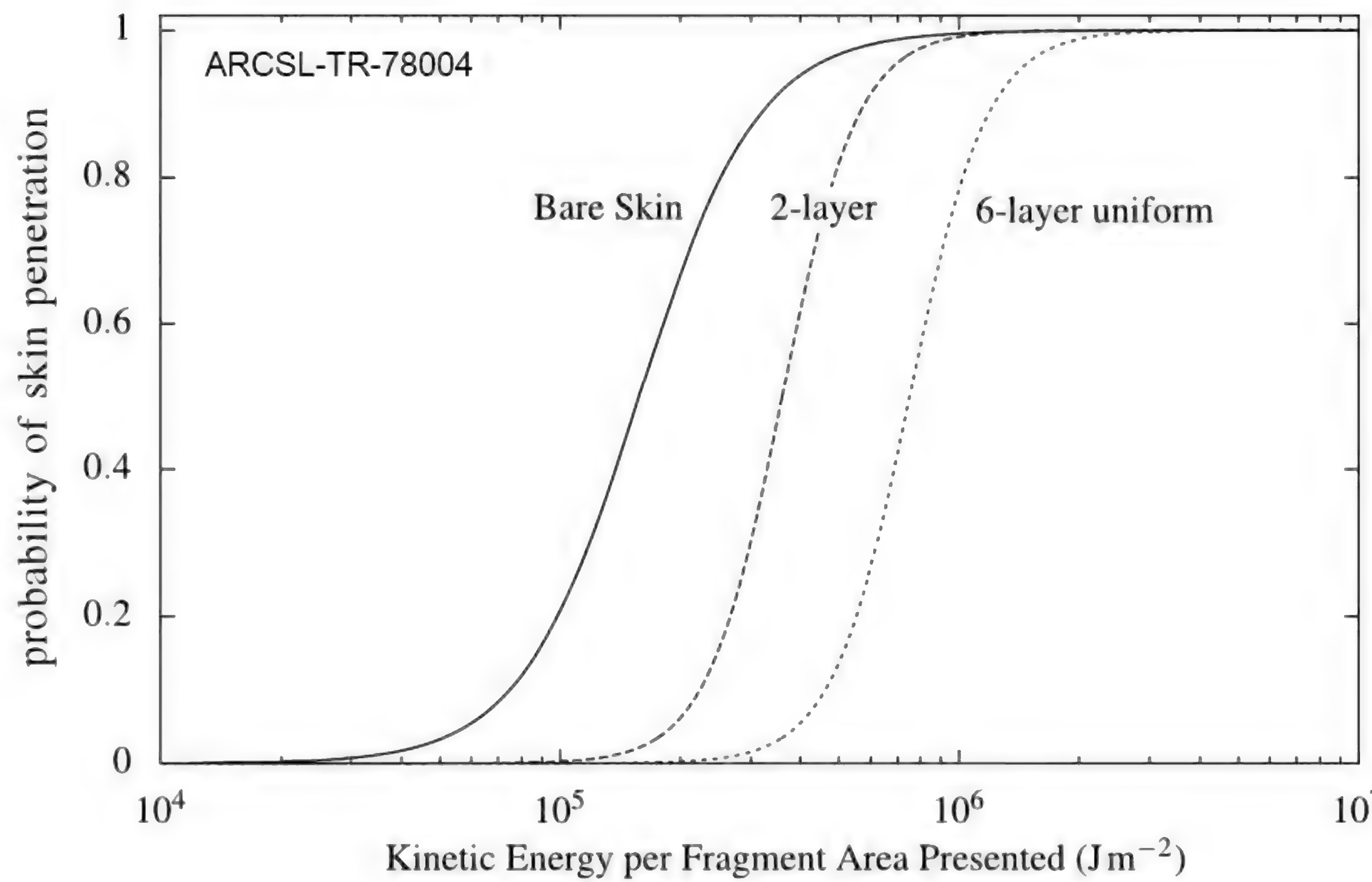
Figure 17.



all-cotton tee shirt (145 gm/m^2)

cotton-sateen material (285 gm/m^2)


FRAGMENT VELOCITY DEGRADATION
DUE TO COMBAT CLOTHING
V(50%) = K(A/m) + B
K B
CLOTHING: 281.07 73.51
BARE SKIN: 124.71 22.03
COMBAT CLOTHING
BARE HUMAN AND GOAT SKIN
VELOCITY NEEDED FOR 50% INJURY, V(50%), m/s
300
200
100
0
0.2
0.4
0.6
0.8
FRAGMENT AREA PER UNIT MASS, A/m (cm2 per gram)



Lewis, James H., *et al, An Empirical/Mathematical Model to Estimate the Probability of Skin Penetration by Various Projectiles,* Technical Report ARCSL-TR-78004, April 1978, US Army Armament Research and Development Command

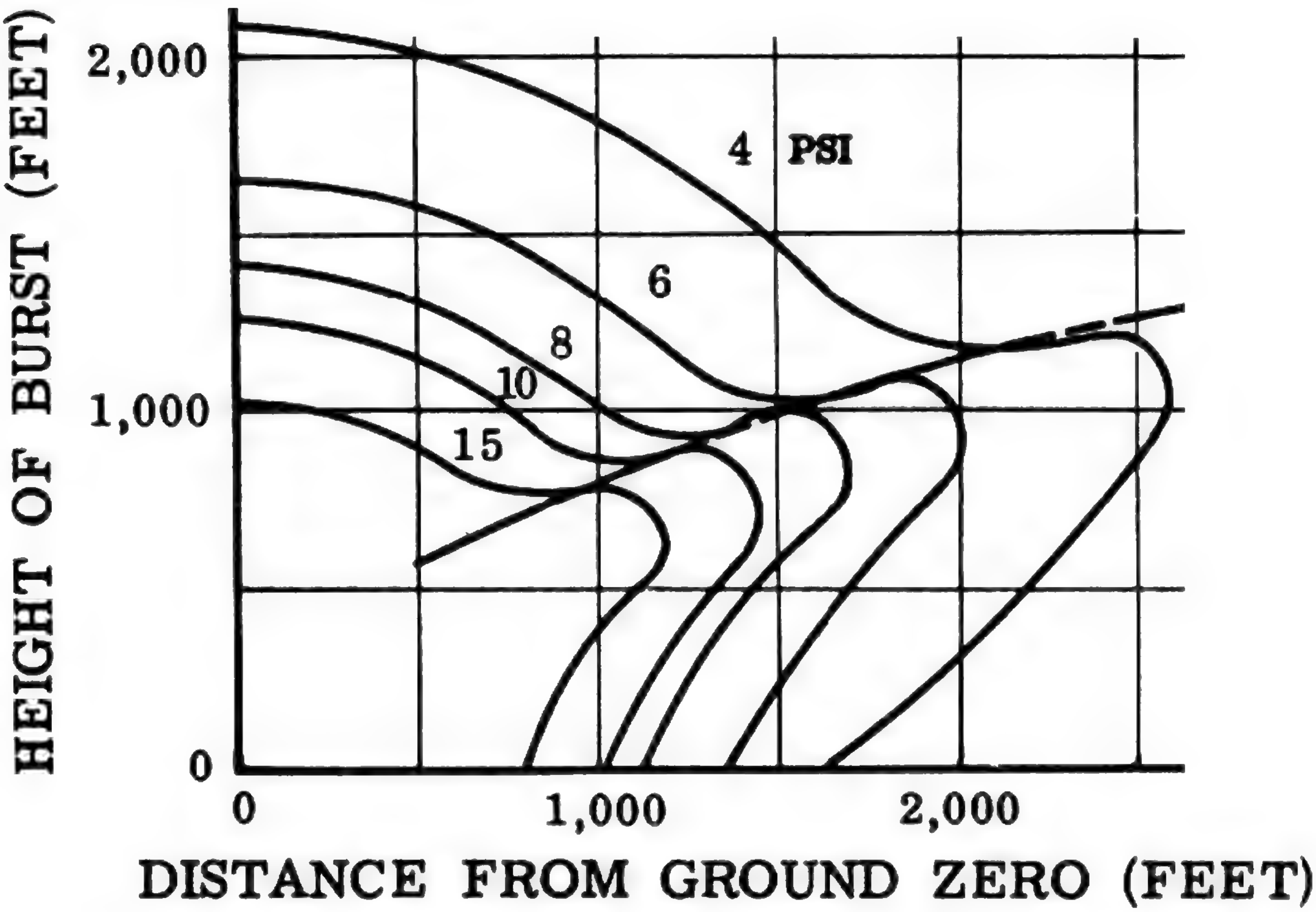
The Effects of Nuclear Weapons (1964)

GLASS PENETRATING ABDOMINAL CAVITY

Mass of glass fragments (grams)	*Probability of penetration (percent)*		
	1	50	99
	Impact velocity (ft/sec)		
0. 1	235	410	730
1. 0	140	245	430

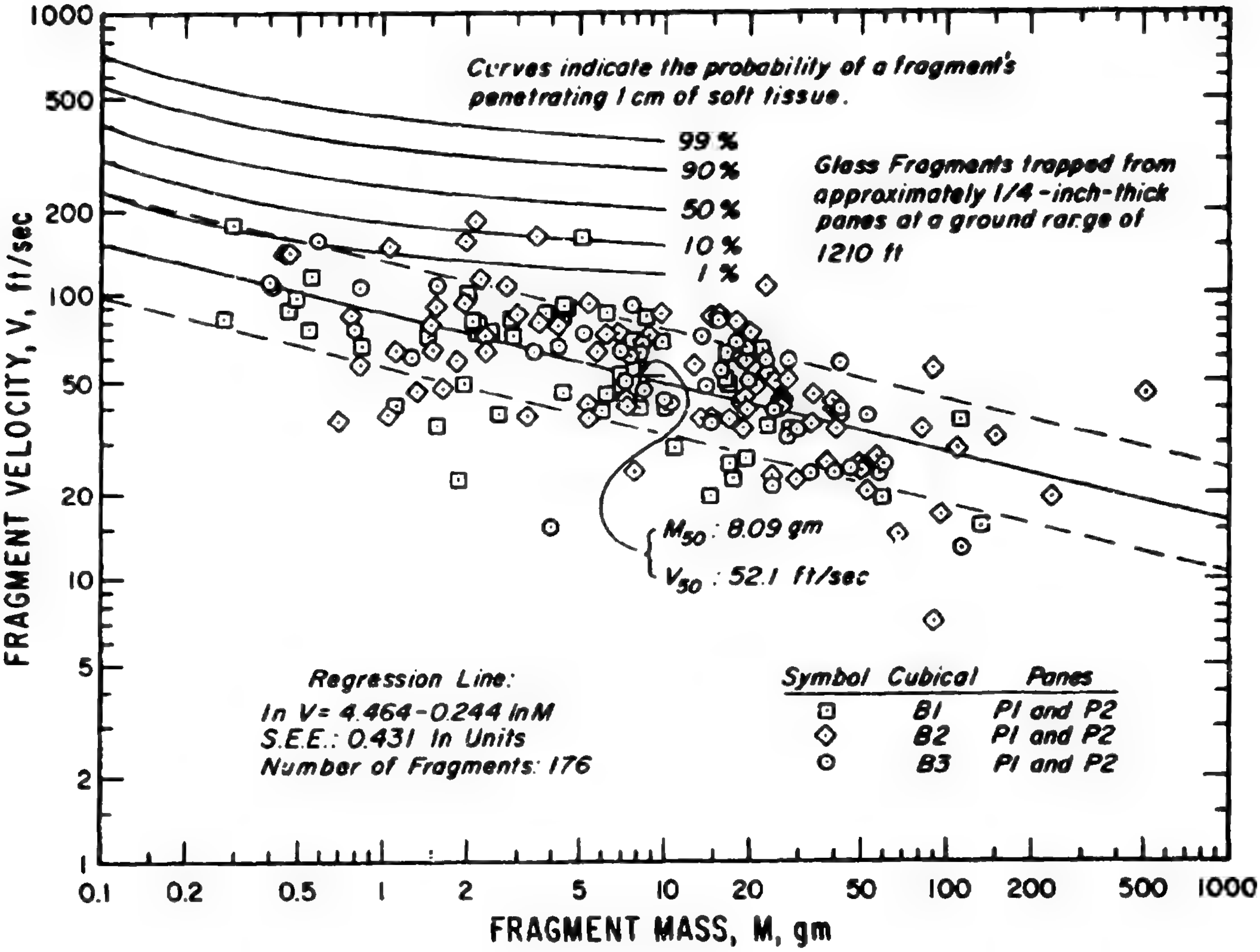
GLASS

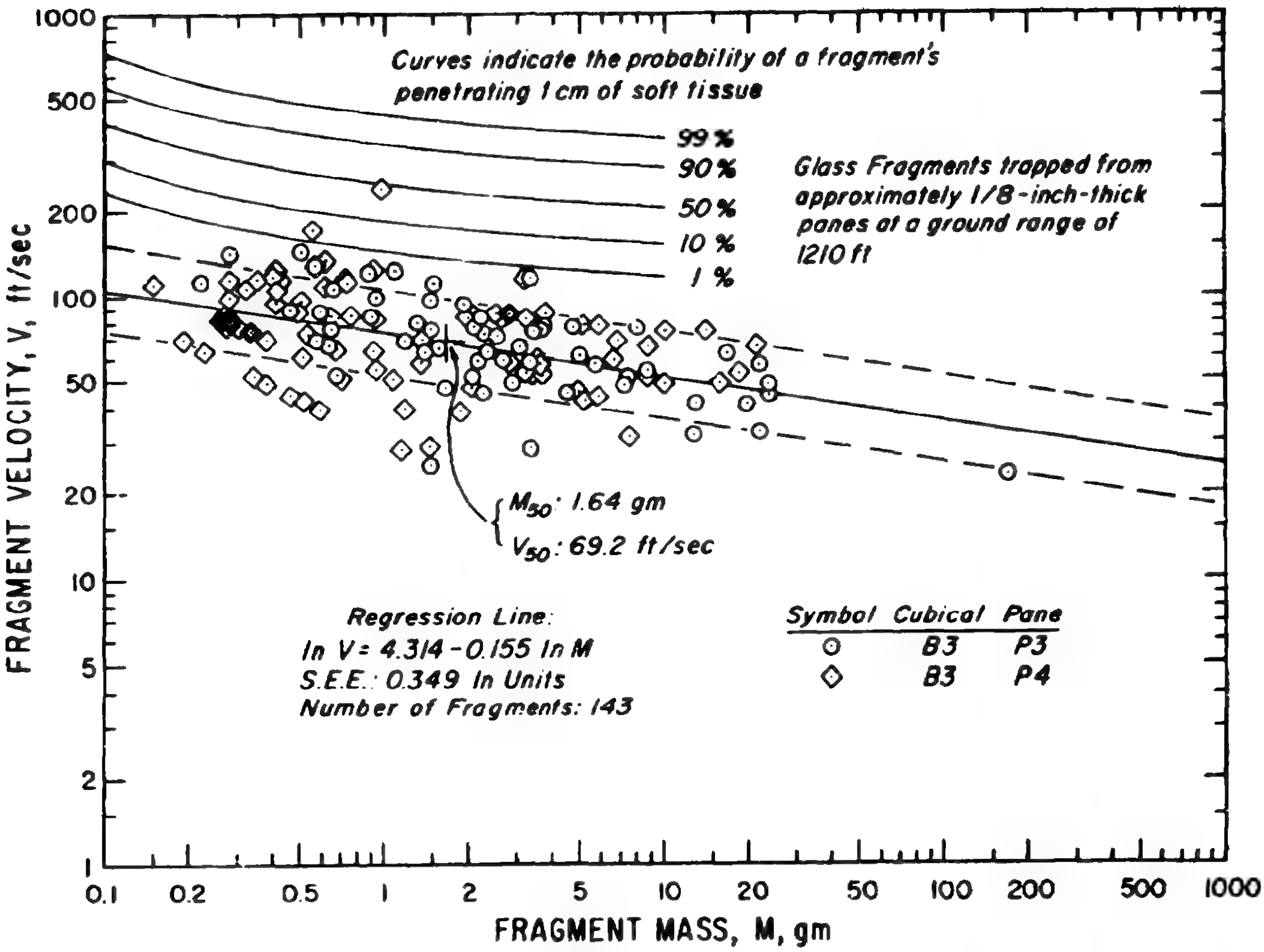
Peak overpressure (psi)	*Median velocity (ft/sec)*	*Median mass (grams)*	*Maximum number per sq ft*
1. 9	108	1. 45	4. 3
5. 0	170	0. 13	388



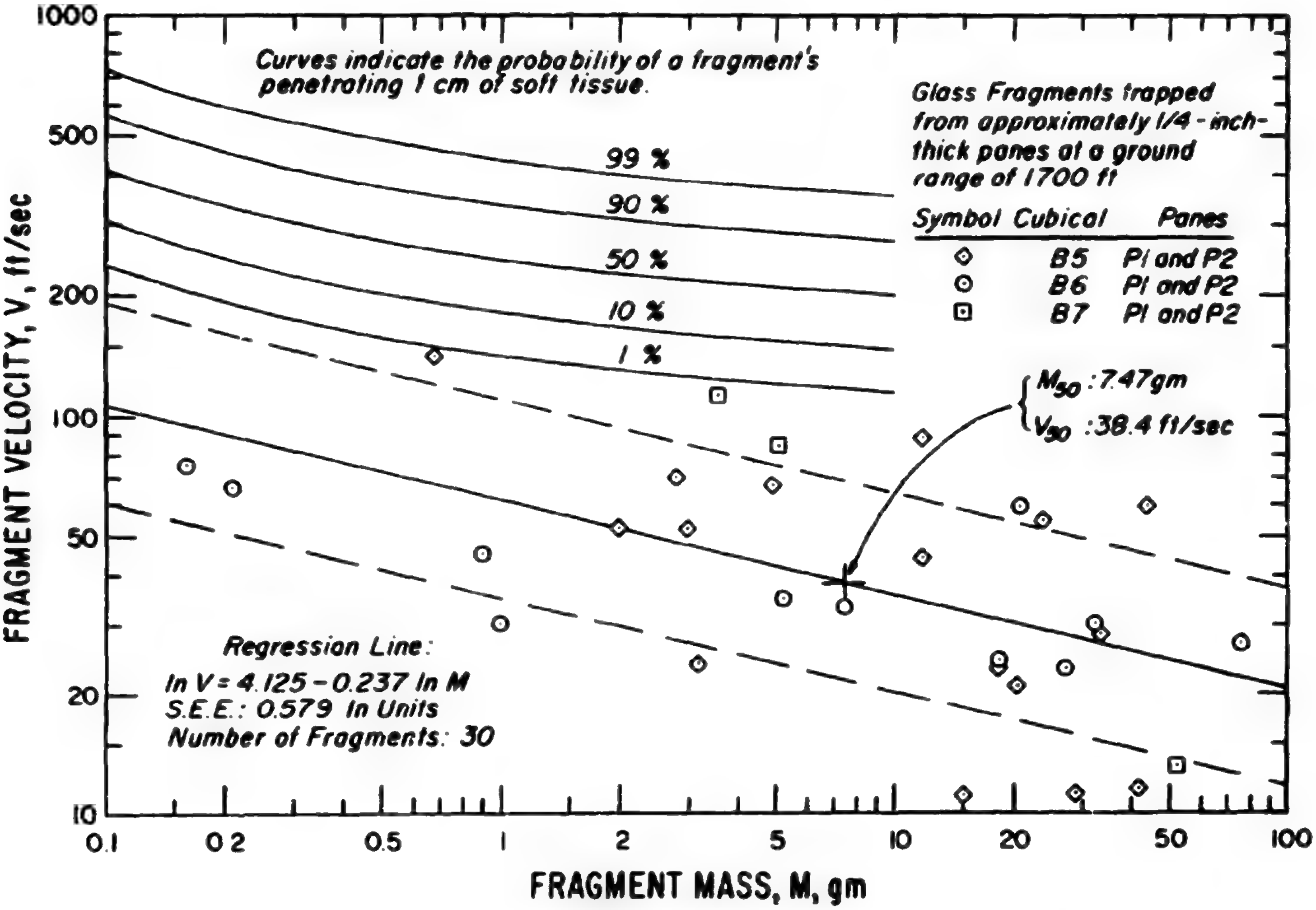
Peak overpressures on the ground for 1-kiloton burst

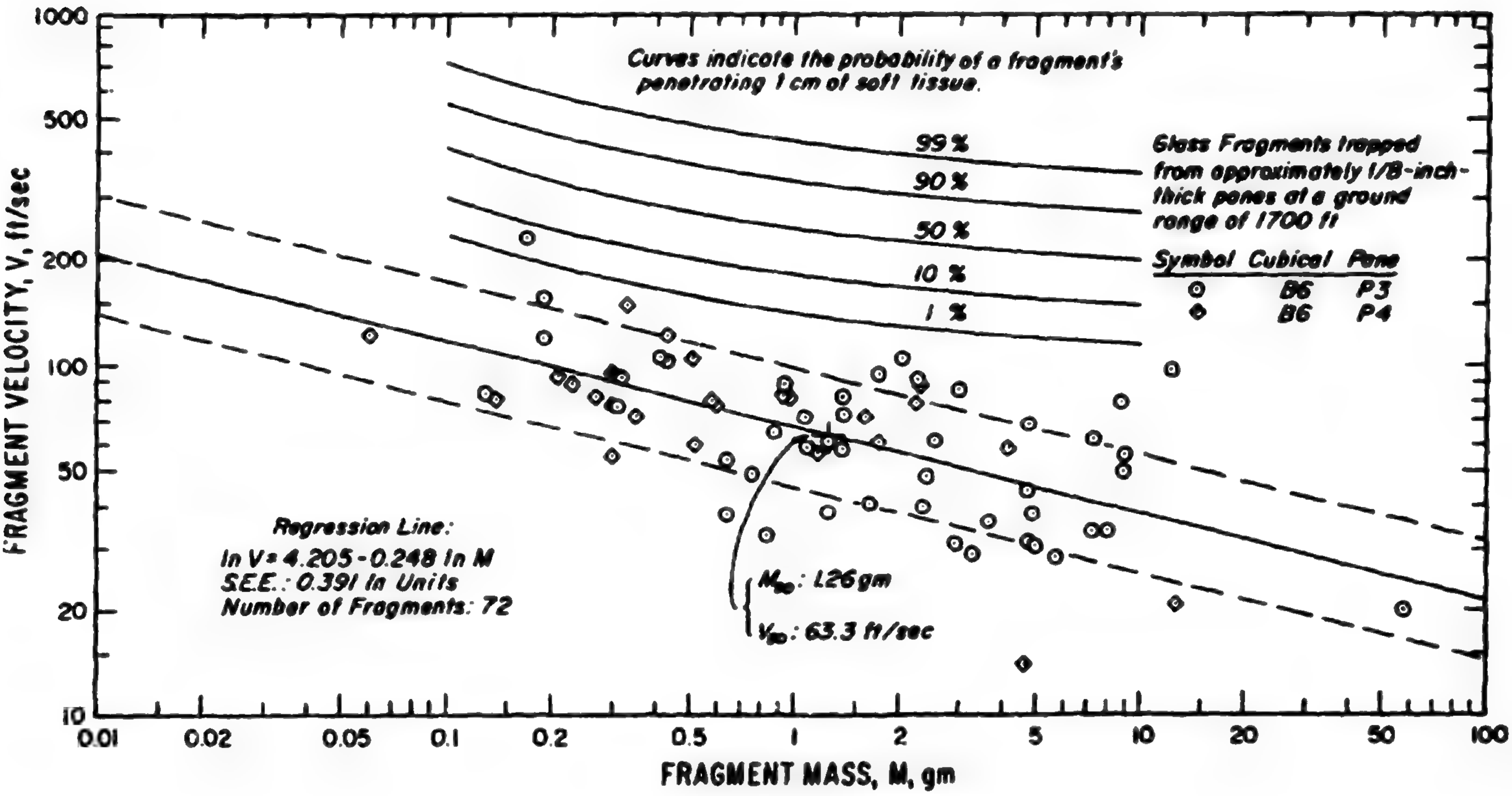
E. R. Fletcher, et al., "Airblast Effects on Windows in Buildings and Automobiles on the Eskimo II Event", in report AD775580, p. 251. Eskimo II was equivalent to 11 tons of TNT, 22 May 1973. Data below: 1,210 ft (0.54 psi incident, 1.1 psi reflected, 0.158 sec)





E. R. Fletcher, et al., "Airblast Effects on Windows in Buildings and Automobiles on the Eskimo II Event", in report AD775580, p. 251. Eskimo II was equivalent to 11 tons of TNT, 22 May 1973. Data below: 1,700 ft (0.41 psi incident, 0.83 psi reflected, 0.180 sec)

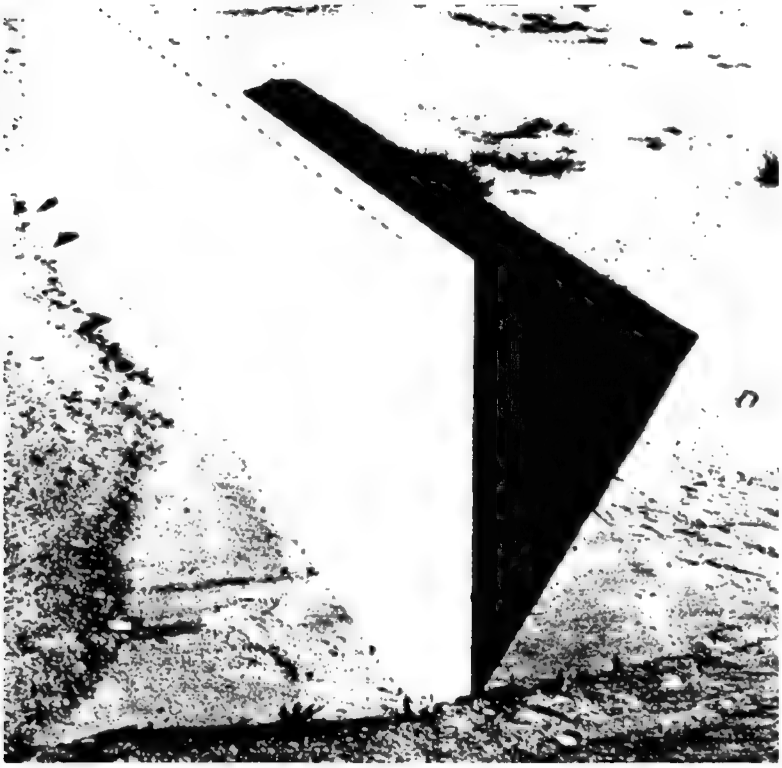




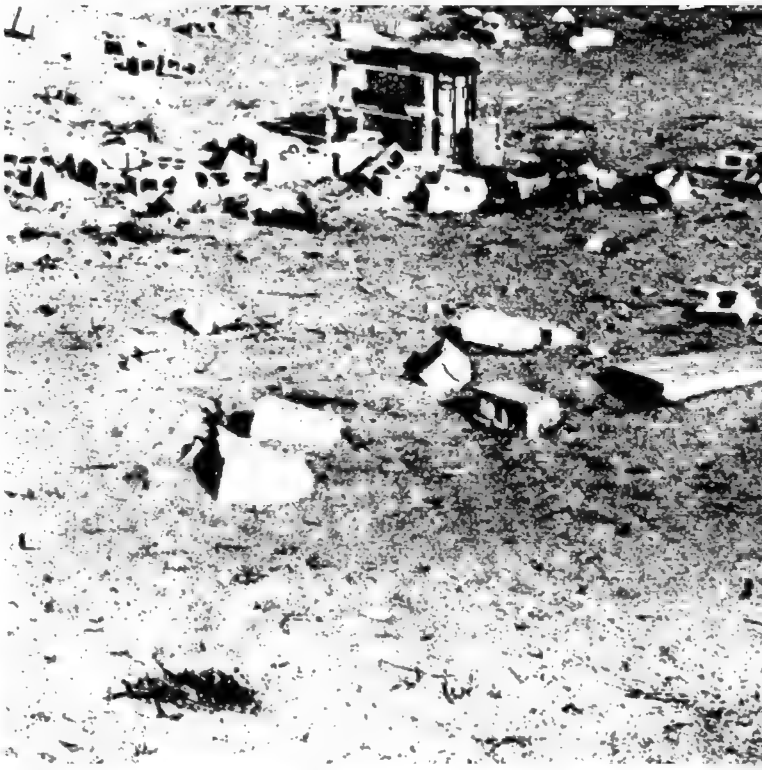
Report to the Test Director WT-1468

SECONDARY MISSILES GENERATED BY NUCLEAR-PRODUCED BLAST WAVES

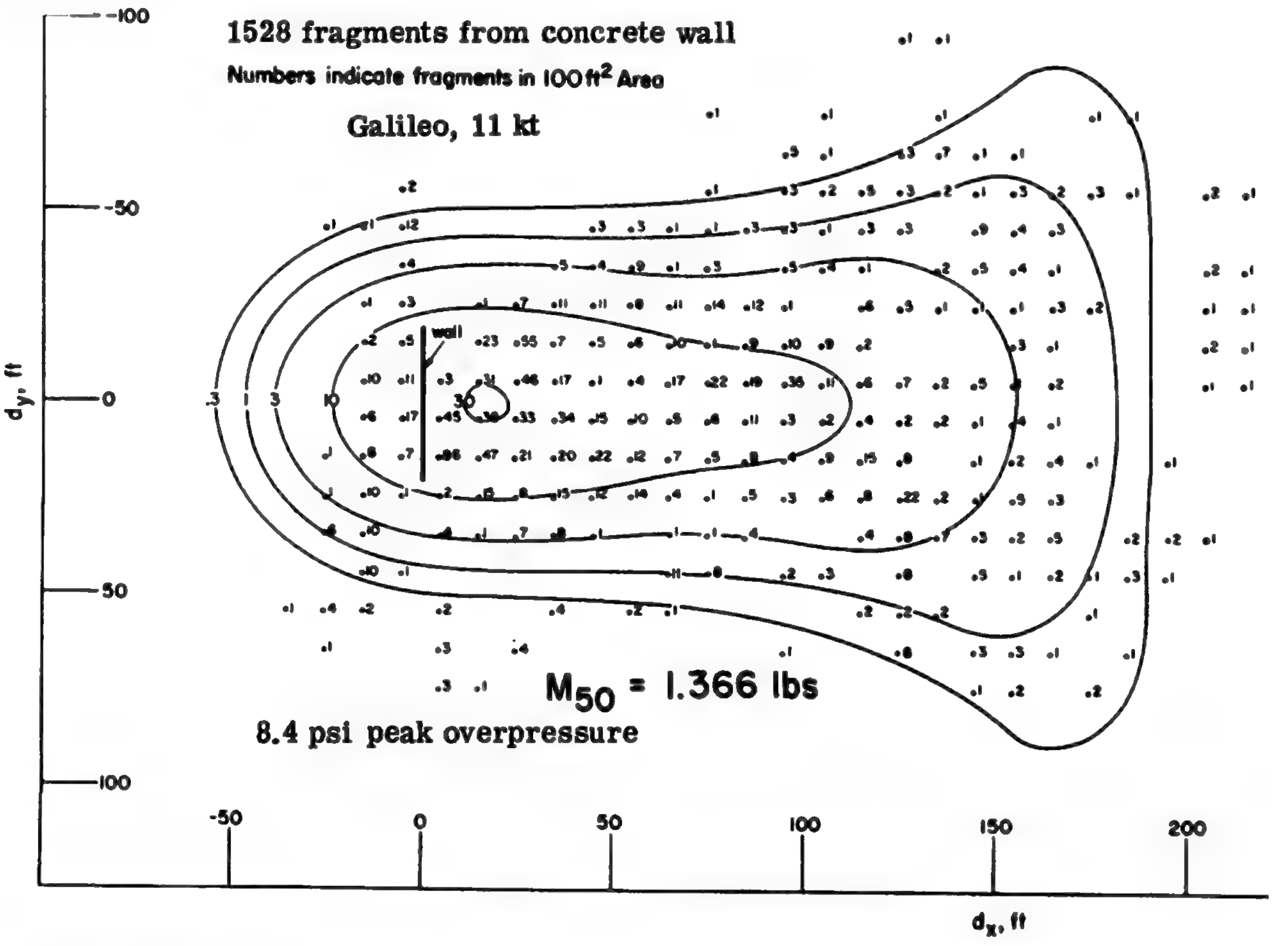
A 40-ft concrete-block wall was built 2750 ft from GZ on shot Galileo, 11 kt



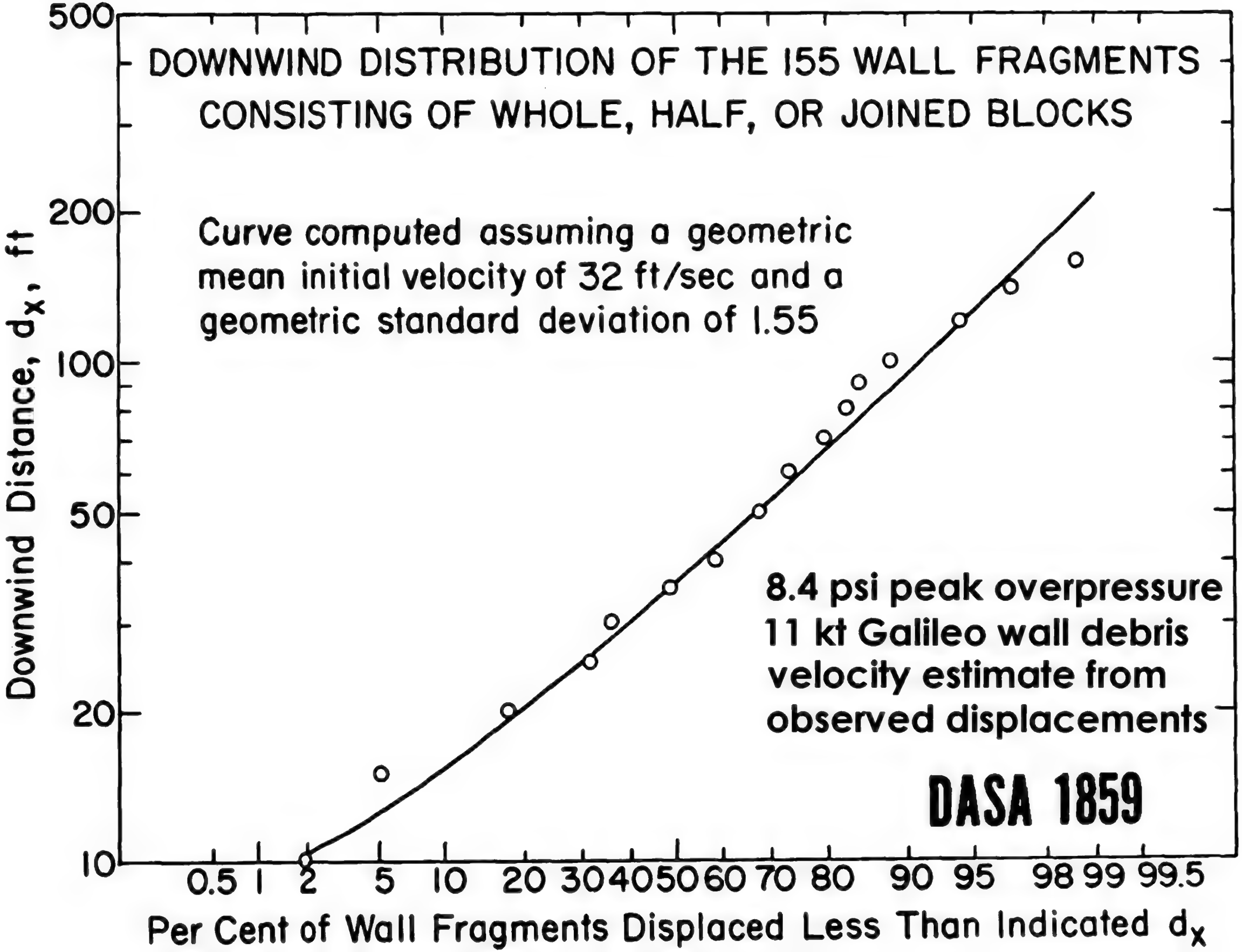
Concrete-block wall (64 in. high, 40 ft long, and 7.5 in. thick) broad side of the wall was oriented toward GZ.

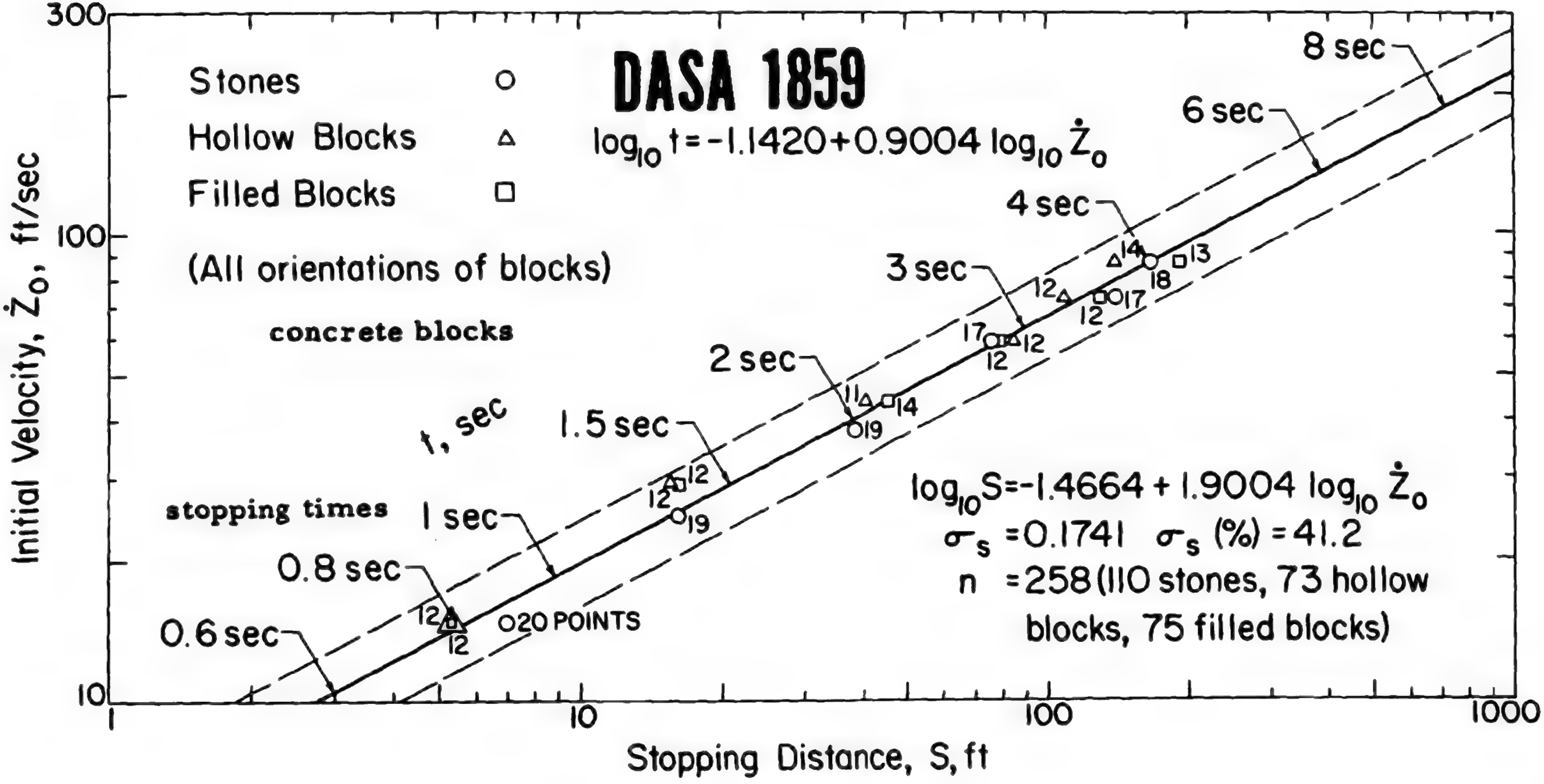


Photograph illustrating the scatter of blocks from the wall
8.4 psi peak overpressure



Spatial distribution of all fragments with masses over 0.1 lb from the concrete-block wall.


DOWNWIND DISTRIBUTION OF THE 155 WALL FRAGMENTS CONSISTING OF WHOLE, HALF, OR JOINED BLOCKS
Curve computed assuming a geometric mean initial velocity of 32 ft/sec and a geometric standard deviation of 1.55
8.4 psi peak overpressure
11 kt Galileo wall debris
velocity estimate from observed displacements
DASA 1859
Downwind Distance, d_x, ft
500
200
100
50
20
10
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
Per Cent of Wall Fragments Displaced Less Than Indicated d_x


DASA 1859
Stones
Hollow Blocks
Filled Blocks
(All orientations of blocks)
concrete blocks
t, sec
stopping times
$\log_{10} t = -1.1420 + 0.9004 \log_{10} \dot{Z}_0$
$\log_{10} S = -1.4664 + 1.9004 \log_{10} \dot{Z}_0$
$\sigma_s = 0.1741 \quad \sigma_s (\%) = 41.2$
n = 258 (110 stones, 73 hollow blocks, 75 filled blocks)
0.6 sec
0.8 sec
1 sec
1.5 sec
2 sec
3 sec
4 sec
6 sec
8 sec
20 POINTS
Initial Velocity, $\dot{Z}_0$, ft/sec
Stopping Distance, S, ft
300
100
10
1
10
100
1000

Average Minimal Impact Velocities From a 10 lb. Missile Expected to Cause Skull Fracture and Maximal Velocity Without Fracture

Region of blow	Impact velocities expected to fracture the human skull*	
	ft/sec	mph
Maximal without fracture	23.1	15.7
Minimal with fracture	14.6	9.9

*Computed from the data of Gurdjian, et al. using human material

ORNL-TM-3396

NUCLEAR WEAPONS FREE-FIELD ENVIRONMENT RECOMMENDED FOR INITIAL RADIATION SHIELDING CALCULATIONS

J. A. Auxier, Z. G. Burson, R. L. French,
F. F. Haywood, L. G. Mooney, and E. A. Straker

Table 8. Fission-Product Gamma Ray Exposure During the First 60 Seconds from a Typical TN Weapon at a 100-M Burst Height

Slant Range (m)	Shock Arrival (sec)	Percent Before Shock	Percent After Shock
	100 KT		
538	0.3678	13.8	86.2
740	0.8187	20.4	79.6
1030	1.822	36.2	63.8
1446	4.055	63.1	36.9
2097	11.02	95.7	4.3
	300 KT		
771	0.5488	13.7	86.3
1060	1.221	20.5	79.5
1472	2.718	38.6	61.4
2065	6.049	69.8	30.2
2995	16.44	98.8	1.2
	1 MT		
1146	0.8187	11.1	88.9
1576	1.822	18.3	81.7
2190	4.055	38.2	61.8
3075	9.024	75.3	24.7
4458	24.53	99.8	0.2

ORNL-TM-3396

NUCLEAR WEAPONS FREE-FIELD ENVIRONMENT RECOMMENDED FOR INITIAL RADIATION SHIELDING CALCULATIONS

J. A. Auxier, Z. G. Burson, R. L. French, F. F. Haywood, L. G. Mooney, and E. A. Straker

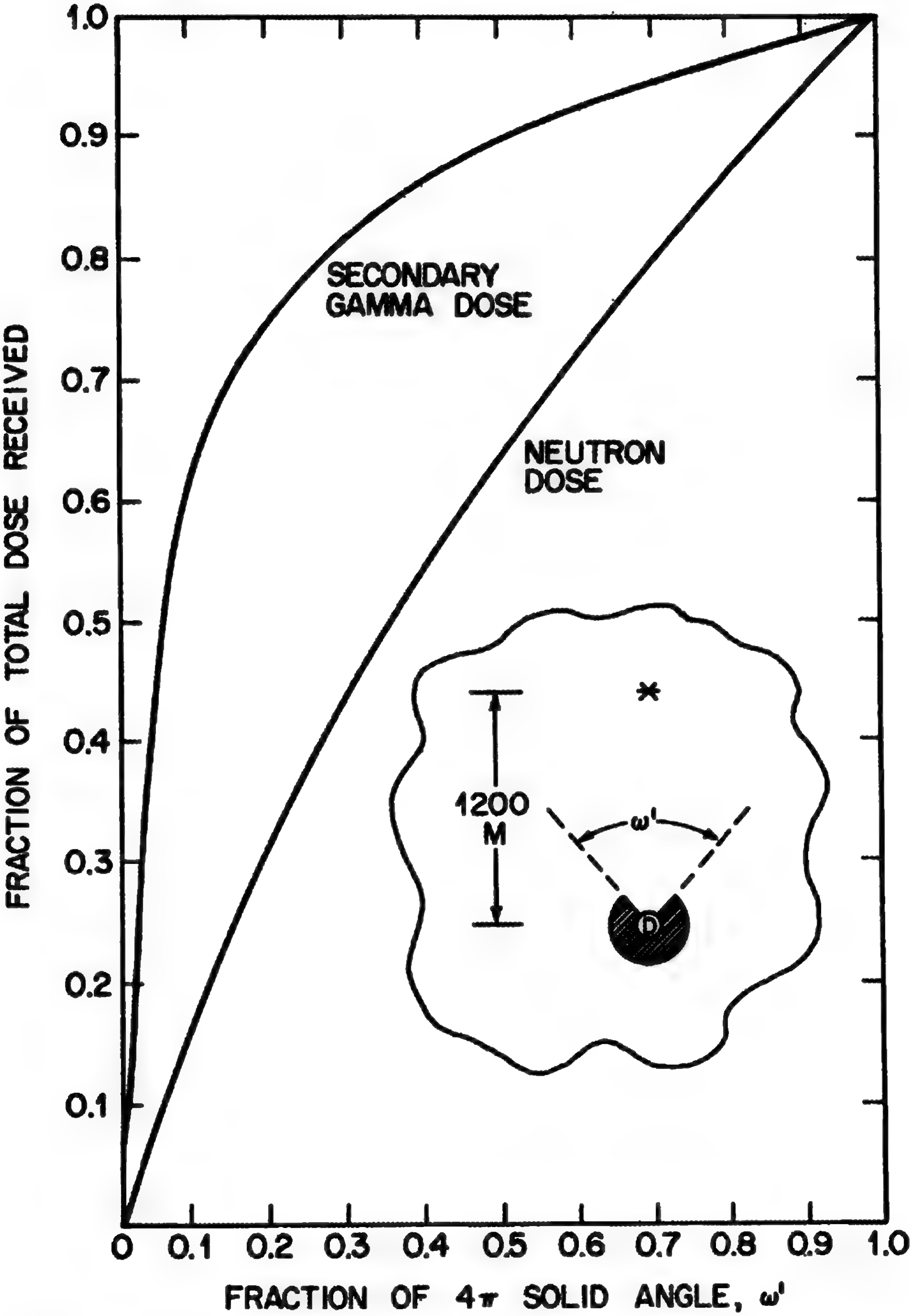


Figure 9. Angular Distribution of Neutron and Secondary Gamma 1200 m from a Thermonuclear Weapon

HIROSHIMA

John Hersey

NEW YORKER *of* 31 *August*, 1946

I

A NOISELESS FLASH

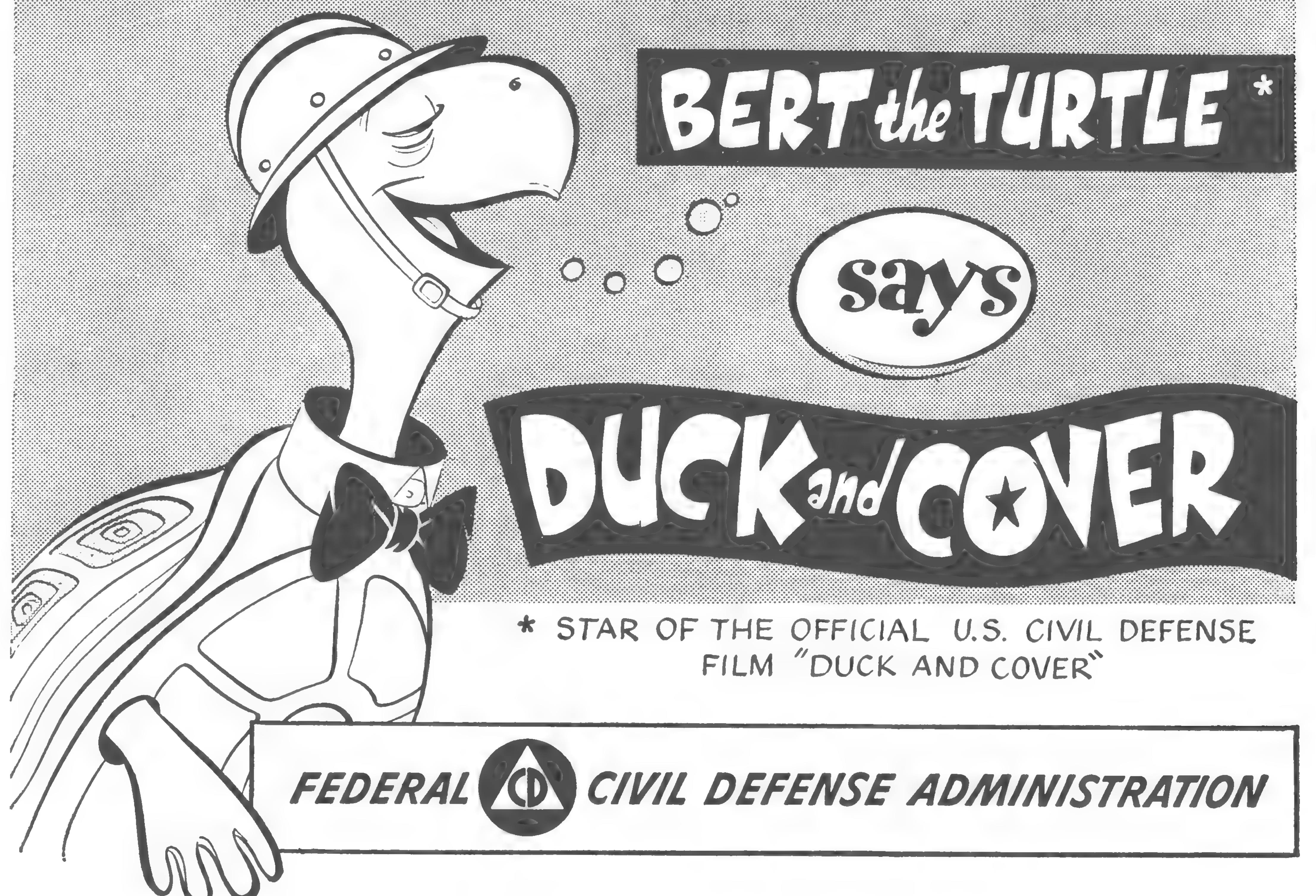
AT exactly fifteen minutes past eight in the morning, on August 6th, 1945, Japanese time, at the moment when the atomic bomb flashed above Hiroshima,

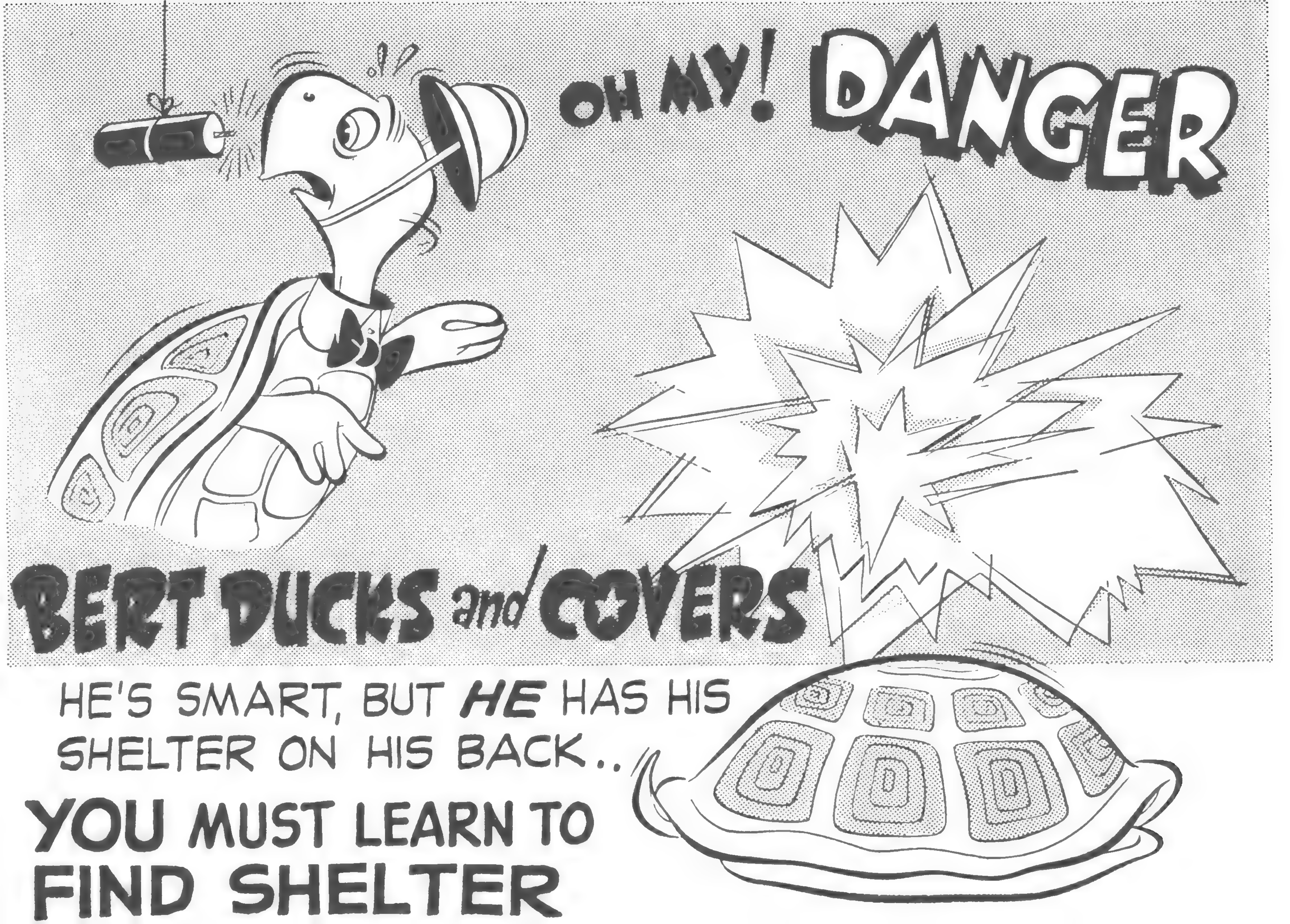
Dr. Terufumi Sasaki, a young member of the surgical staff of the city's large, modern Red Cross Hospital, walked along one of the hospital corridors

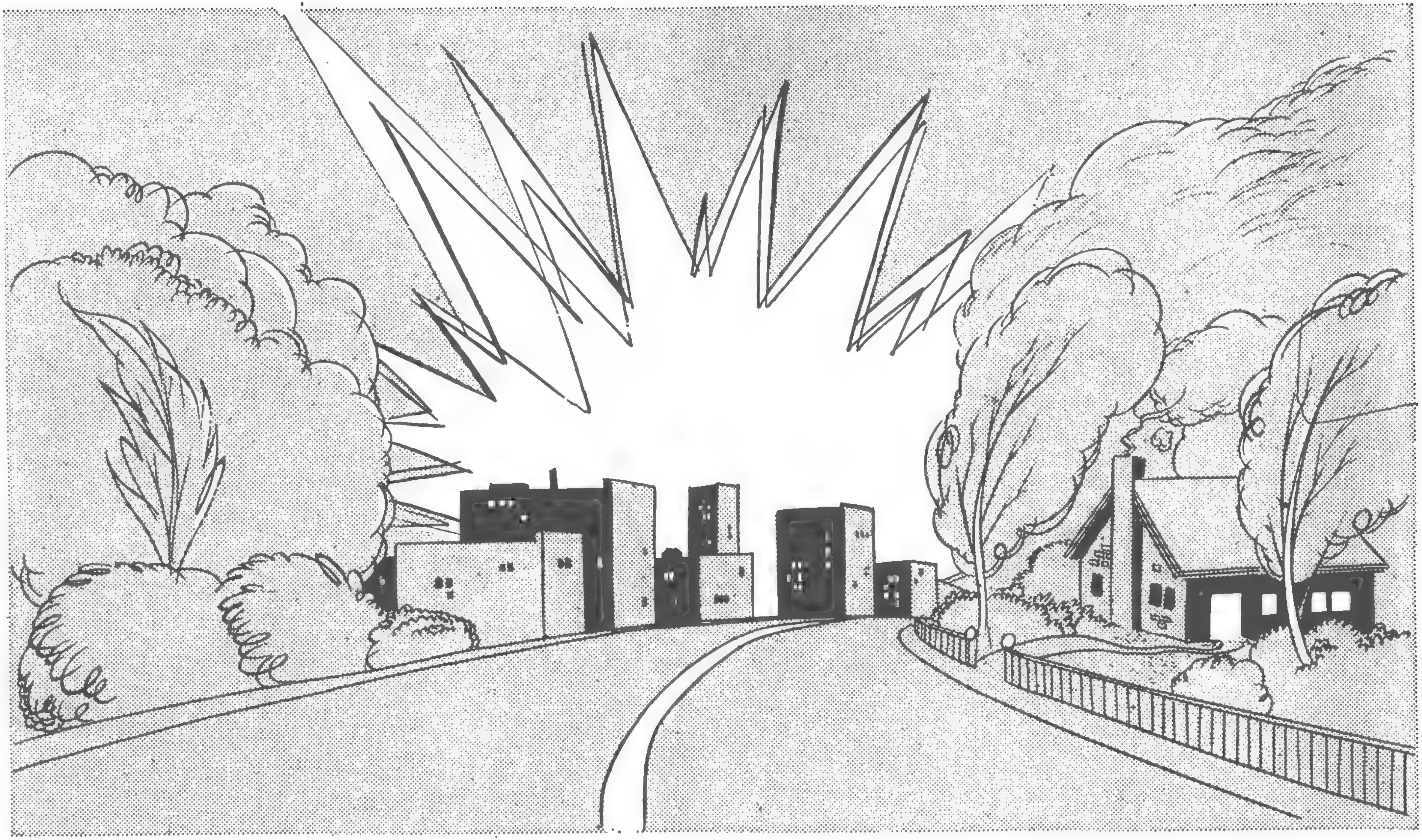
He was one step beyond an open window when the light of the bomb was reflected, like a gigantic photographic flash, in the corridor. He ducked down on one knee and said to himself, as only a Japanese would, "Sasaki, *gambare !* Be brave !" Just then (the building was 1,650 yards from the centre), the blast ripped through the hospital. The glasses he was wearing flew off his face; the bottle of blood crashed against one wall; his Japanese slippers zipped out from under his feet—but otherwise, thanks to where he stood, he was untouched.

Dr. Sasaki shouted the name of the chief surgeon and rushed around to the man's office and found him terribly cut by glass.

Starting east and west from the actual centre, the scientists, in early September, made new measurements, and the highest radiation they found this time was 3.9 times the natural "leak."

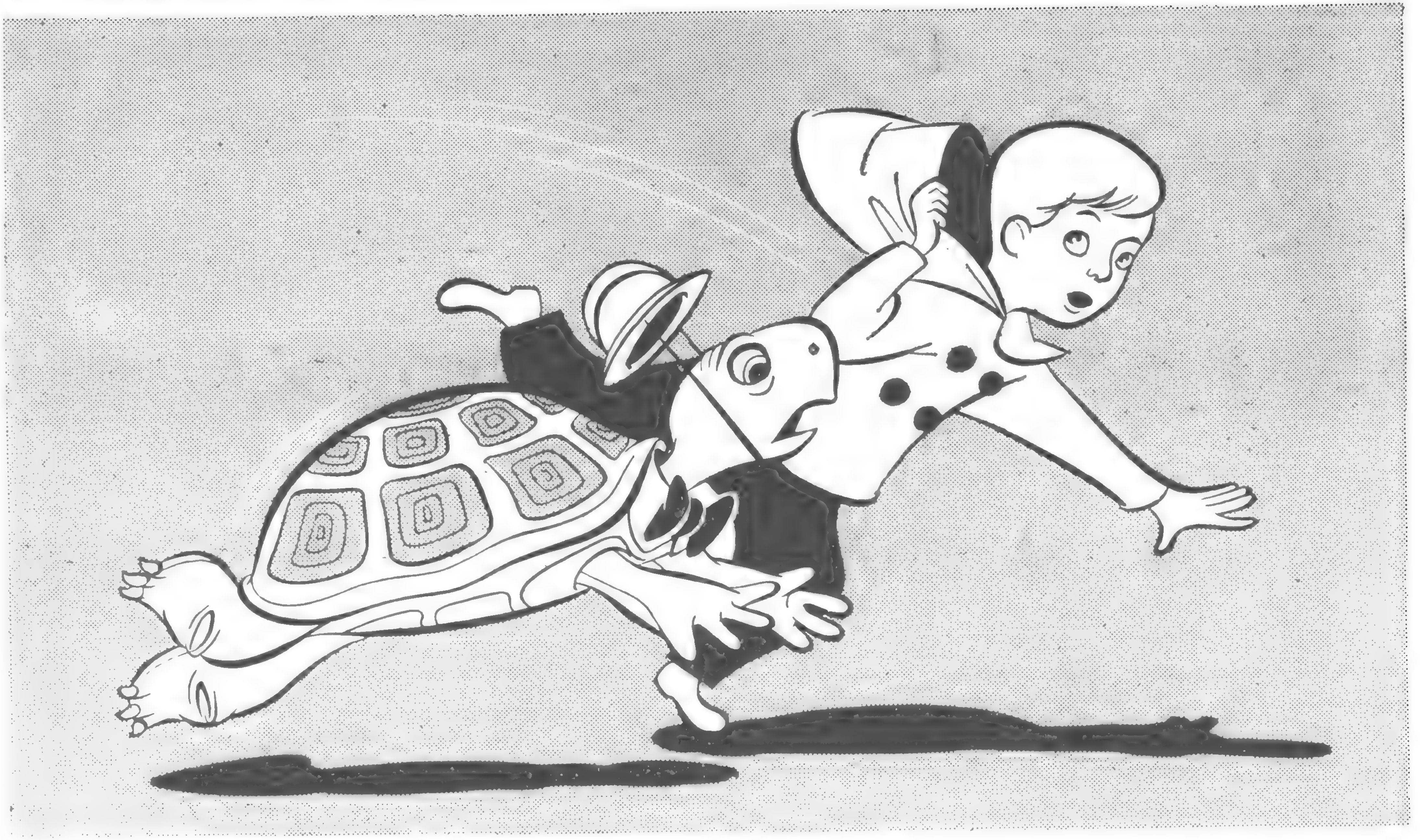

BERT the TURTLE *
says
DUCK and COVER
* STAR OF THE OFFICIAL U.S. CIVIL DEFENSE FILM "DUCK AND COVER"
FEDERAL CD CIVIL DEFENSE ADMINISTRATION


OH MY! DANGER
BERT DUCKS and COVERS
HE'S SMART, BUT HE HAS HIS
SHELTER ON HIS BACK..
YOU MUST LEARN TO
FIND SHELTER

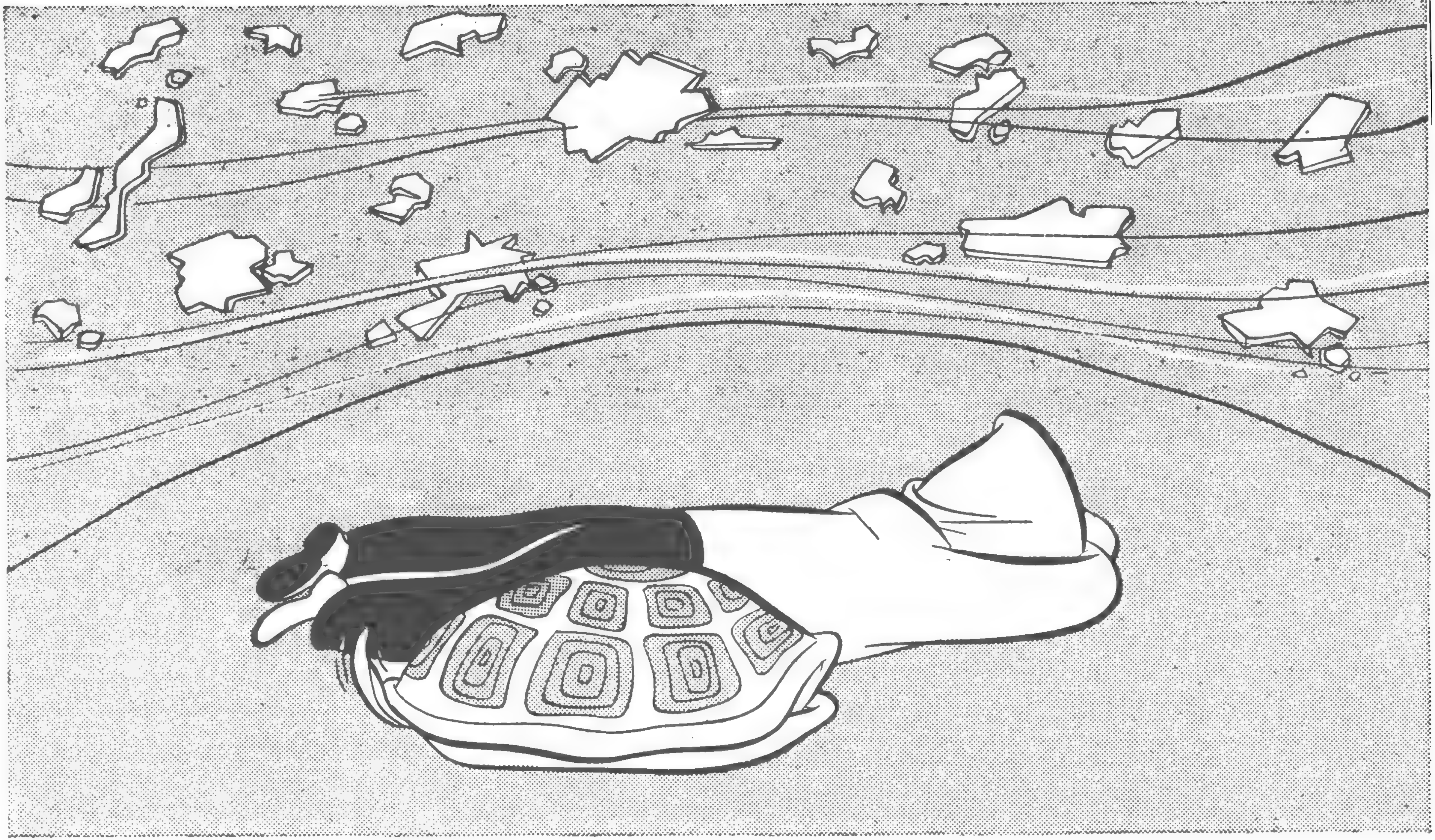


THE ATOMIC BOMB IS A **NEW** DANGER. IT EXPLODES WITH A FLASH BRIGHTER THAN ANY YOU'VE EVER SEEN.

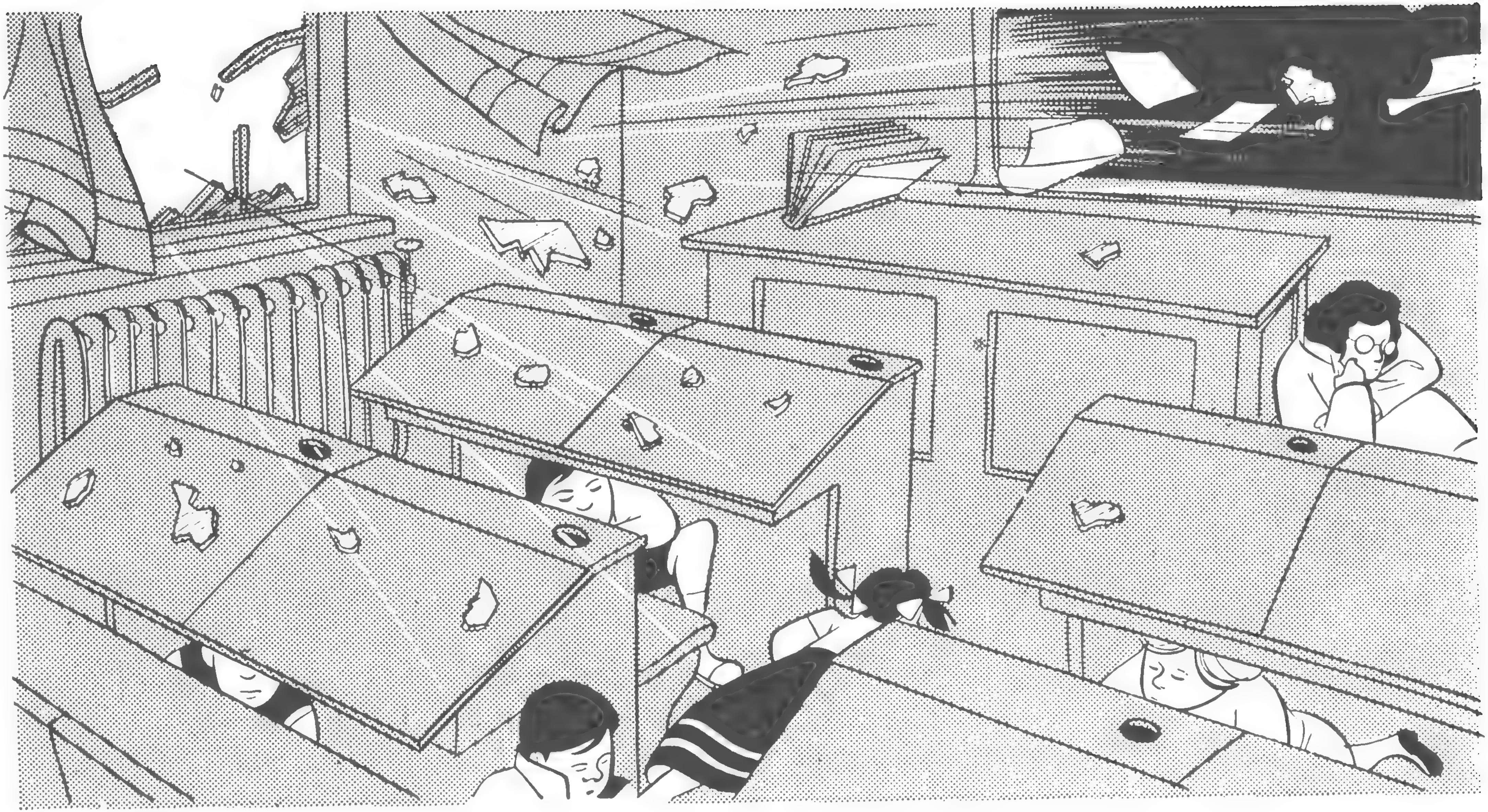
THINGS WILL BE KNOCKED DOWN ALL OVER TOWN, AND, AS IN A BIG WIND, THEY ARE BLOWN THROUGH THE AIR. **YOU** MUST BE READY TO PROTECT YOURSELF.



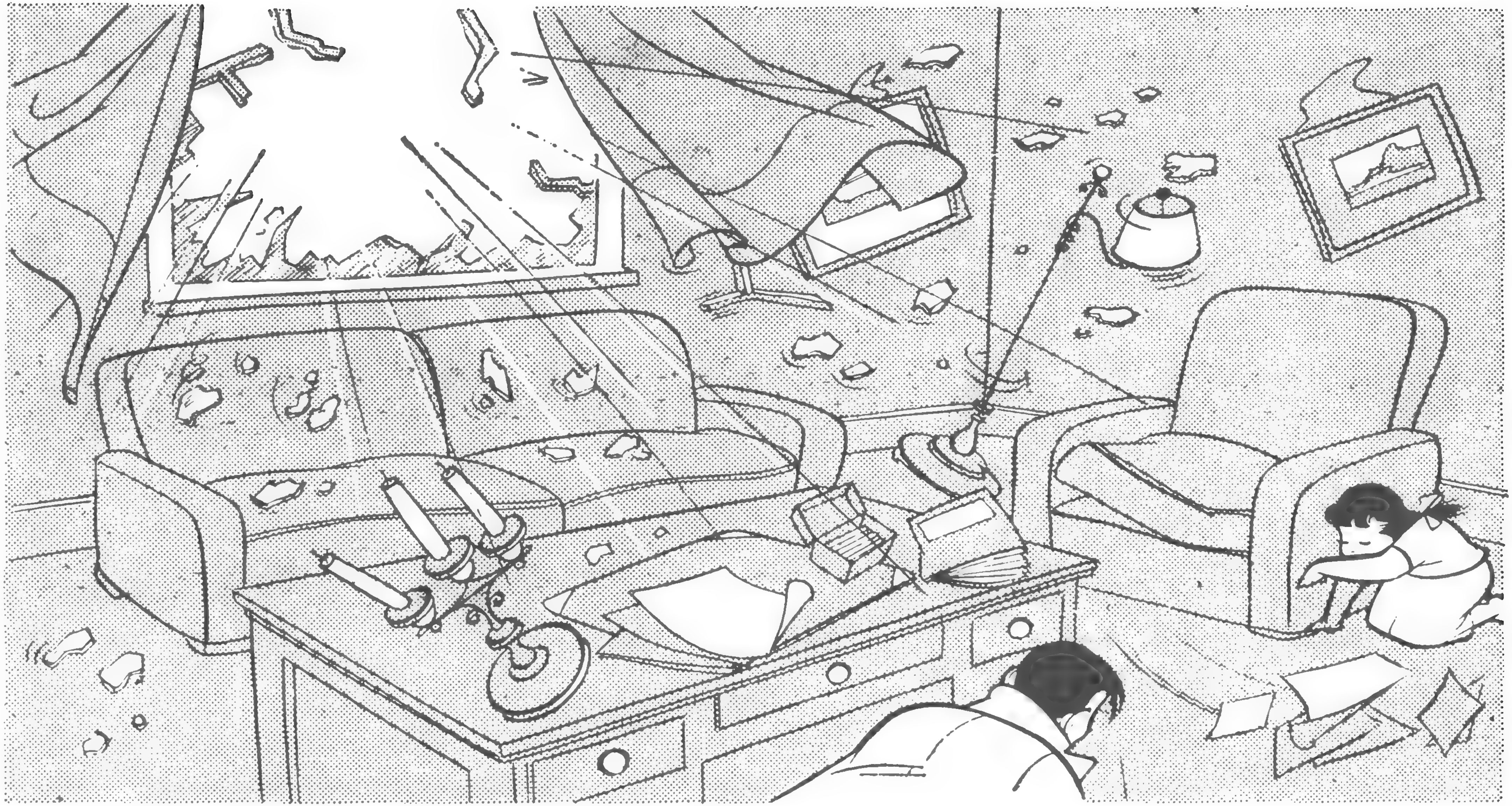
SO, LIKE BERT, YOU **DUCK** TO AVOID
THE THINGS FLYING THROUGH THE AIR...



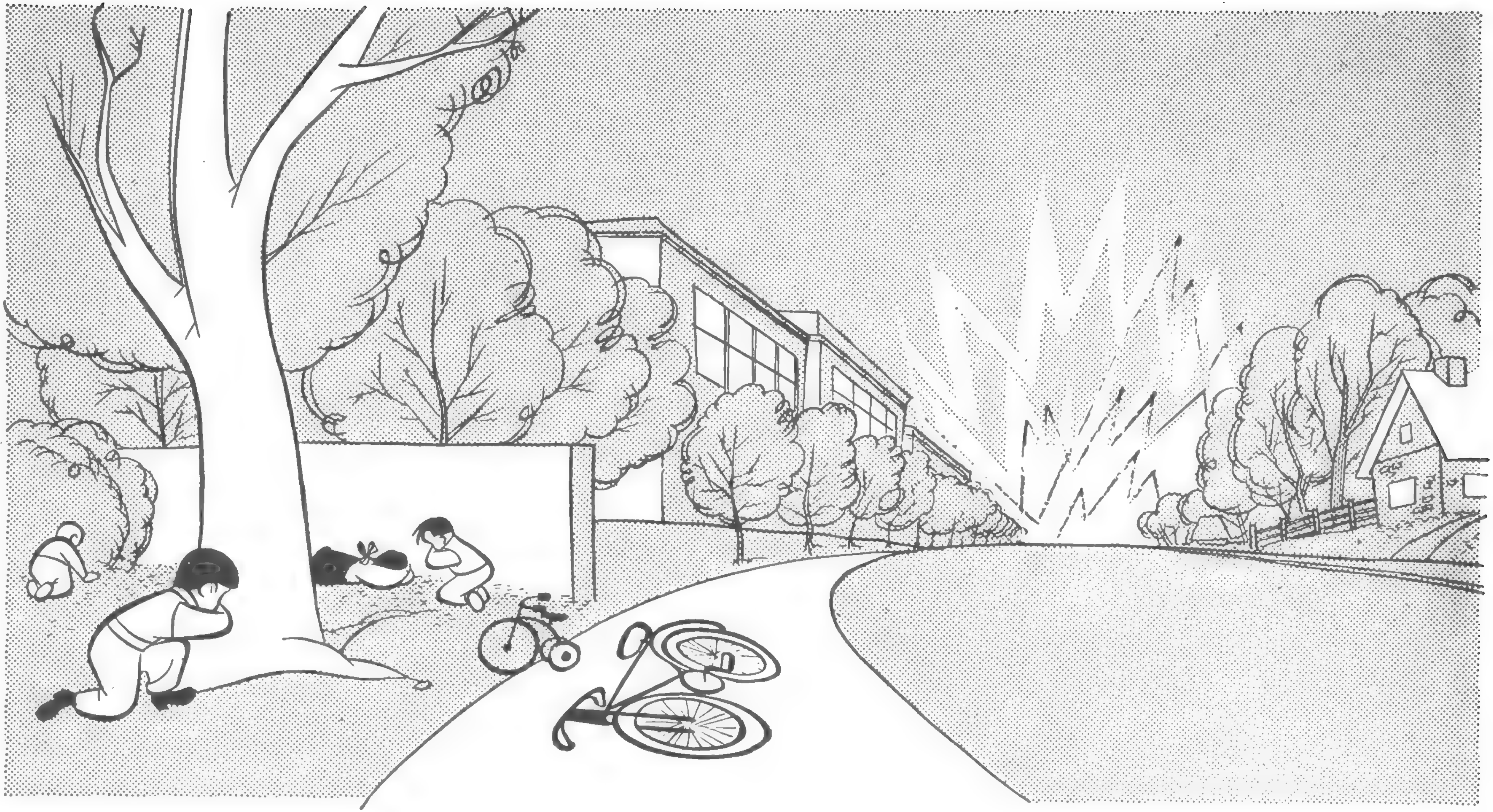
...AND **COVER** TO KEEP FROM GETTING CUT OR EVEN BADLY BURNED.



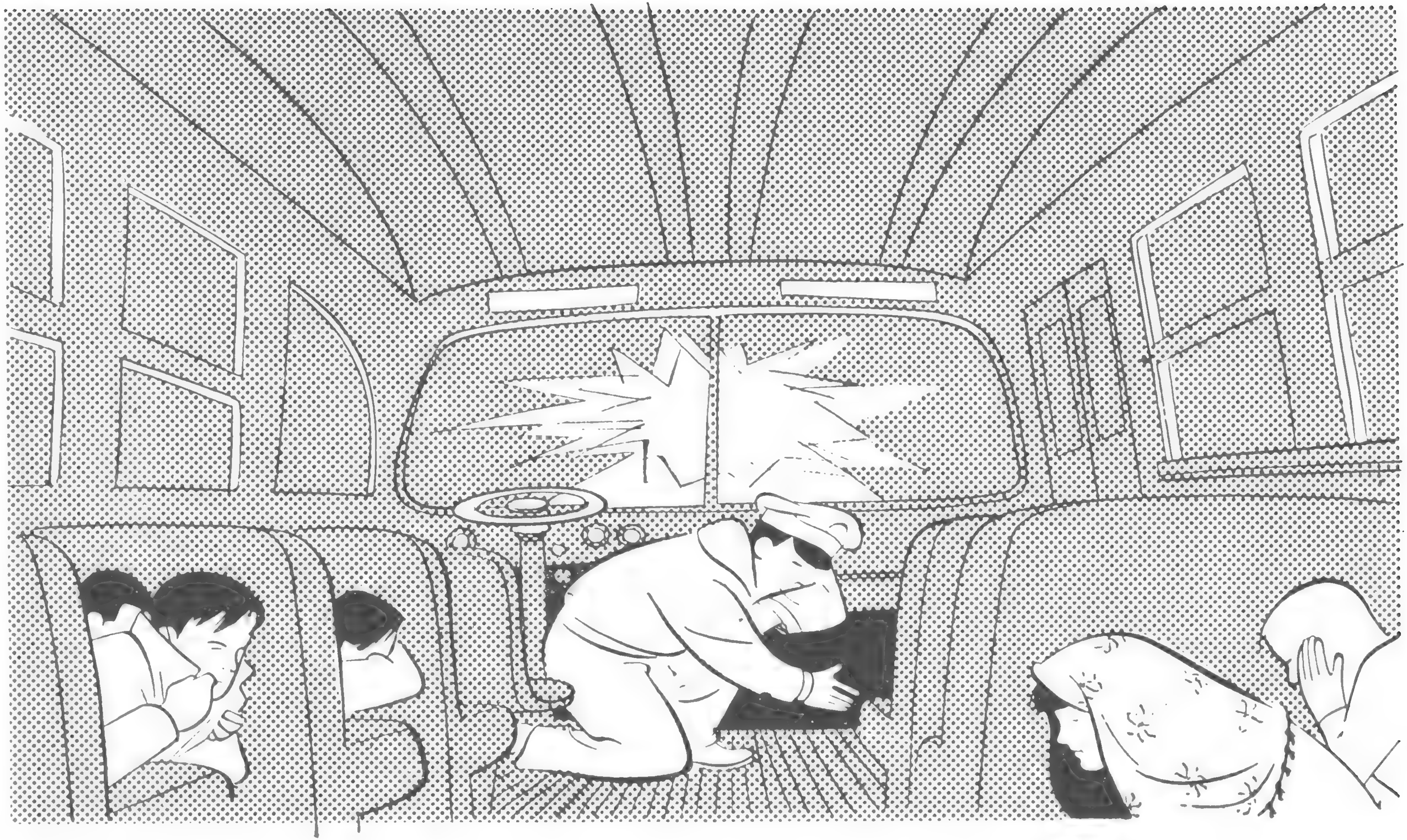
BUT SOMETIMES--**AND THIS IS VERY IMPORTANT**--
THE BOMB MIGHT EXPLODE AND THE BRIGHT FLASH
COME... *WITHOUT ANY WARNING!*



THERE IS *ALWAYS* **SOMETHING** TO SHELTER YOU-INDOORS, A SCHOOL DESK, A CHAIR, A TABLE. ALWAYS DUCK AWAY FROM WINDOWS AND GLASS DOORS.



OUTDOORS, DUCK BEHIND WALLS AND TREES. EVEN IN A HOLLOW IN THE GROUND. IN A BUS OR AUTO, DUCK DOWN BEHIND OR UNDER THE SEATS.



BUT REMEMBER... **DO IT INSTANTLY...**
DON'T STAND AND LOOK. DUCK AND COVER!

cue for survival

OPERATION CUE

A.E.C. NEVADA TEST SITE

MAY 5, 1955

A report by the FEDERAL CIVIL DEFENSE ADMINISTRATION

EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
Director, Atomic Test Operations, FCDA

The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

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BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima.

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Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing.

142

For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.

143

If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

... For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.

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STUDIES ON FLASH BURNS:

THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

George Mixter, Jr., M. D. and Herman E. Pearse, M. D.

THE UNIVERSITY OF ROCHESTER

ABSTRACT

Fabric interposed between a carbon arc source and the skin of Chester White pigs increased the amount of thermal energy required to cause 2+ burns. For the 2, 4 and 6 layers of fabric studied this increase was 3.6, 38 and over 104 cal/cm^2 respectively when the inner layer of fabric was in contact with the skin. Separation of the inner layer from the skin by 5 mm increased the protective effect of the 2 layer combination from 7.4 to 29 cal/cm^2, provided the outer layer was treated for fire retardation. If the outer layer was not so treated, sustained flaming occurred which in itself added to the thermal burn.

INTRODUCTION

In the past, work in this laboratory has been directed toward a study of flash burns in unshielded skin. It is well known from the atomic bombing in Japan that this type of burn was modified by clothing. A laboratory analysis of the protective effect of fabrics against flash burns was begun (5) by shielding the skin with a few representative fabrics and their combinations.

1. 2 Layers
   a. light green oxford
      knitted cotton underwear
   b. light green oxford (HPM)
      knitted cotton underwear
2. 4 Layers
   olive green sateen
   thin cotton oxford
   wool-nylon shirting
   knitted cotton underwear
3. 6 Layers
   olive green sateen
   thin cotton oxford
   mohair frieze
   rayon lining
   wool-nylon shirting
   knitted wool underwear

5. Morton, J. H., Kingsley, H. D., and Pearse, H. E., "Studies on Flash Burns: The Protective Effects of Certain Fabrics", Surgery, Gynecology and Obstetrics, 94, 497-501 (April 1952).

~~FIDENTIAL~~

WT-770

Copy No.

Operation
UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS

TECHNICAL
of the
DEFENSE
AGENC

AUG

March - June 1953

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Project 8.5

THERMAL RADIATION PROTECTION AFFORDED TEST ANIMALS BY FABRIC ASSEMBLIES

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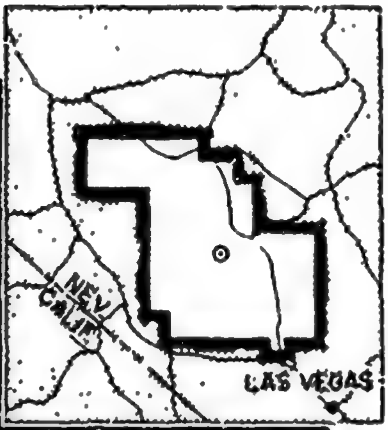

AD B951673

HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS PROJECT
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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WT-770

This document consists of 64 pages

No. 196 of 295 copies, Series A

OPERATION UPSHOT-KNOTHOLE

Project 8.5

THERMAL RADIATION PROTECTION AFFORDED TEST ANIMALS BY FABRIC ASSEMBLIES

REPORT TO THE TEST DIRECTOR

by

J. Fred Oesterling and Staff

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July 1955

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Quartermaster Research and Development Laboratories
Army Medical Service Graduate School
Walter Reed Army Medical Center
University of Rochester Atomic Energy Project

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CHAPTER 4

DISCUSSION

4.1 ANTICIPATED AND OBSERVED RESULTS

4.1.1 Protection Afforded by the Various Uniform Assemblies

Perhaps the most outstanding result of these tests was the degree of thermal protection afforded the test animals by the various uniform assemblies. At the higher levels of radiant energy, where laboratory tests (with the carbon arc) indicated that the animals should have sustained at least 2+ burns, [7] an unexpected degree of protection was found in the field. In the laboratory, thermal energies as low as 44 cal/cm^2 (delivered in 2 sec.) were sufficient to produce burns in pigs' skin under the four layers of the Temperate ensemble. In the field the maximum level at which any animals, clothed in the Temperate uniform, were recovered alive on Shots 9 and 10 was 26.0 cal/cm^2 and one at 48 cal/cm^2 (calc.) on Shot 2. Although no animals were recovered alive at the maximum exposure level of 75 cal/cm^2, there was a complete lack of any evidence to indicate that the animals would have suffered burns from the primary effects of the thermal radiation. Some of the animals wearing the Temperate uniform not treated for fire resistance sustained minor skin burns, but these resulted from exothermic reactions (flame or glow) and occurred only at the more distant stations. Damage to the fabric itself from direct thermal radiation was also less serious than expected, being limited to the two outer layers, whereas in the laboratory three of the layers were damaged and the underwear layer discolored at 40 to 60 cal/cm^2.

The two-layer HW 50/50 and HWFR 50/50 assemblies had not been tested in the laboratory with the carbon arc, although tests in connection with napalm studies had indicated that the wool/cotton underwear of this combination might be quite effective. The outstanding results obtained in the field with these fabric assemblies, however, exceeded the most optimistic anticipations. Exceptionally good thermal protection was observed up to the closest stations from which data were obtained: 41.0 cal/cm^2 for HW 50/50 and 33.5 cal/cm^2 for HWFR 50/50.

Severe burns were sustained by the majority of the pigs wearing the two-layer HW and HWFR assemblies. However, even these thin cotton fabrics were of considerable protective value as can be seen by comparing these results with the bare-skin exposures of the porthole

pigs (Section 3.4). The degree and extent of burns noted beneath these assemblies were less than would have been expected on the basis of previous laboratory experience, especially at the higher calorie levels.

4.1.2 Factors Contributing to the Greater Degree of Thermal Protection in the Field.

There are several conditions encountered in the field, especially at the higher energy levels, but not duplicated in the laboratory (at least not up to the present time) that may account for the fact that like amounts of thermal energy did not produce comparable results in the laboratory and in the field. First, the thermal energy is delivered much more rapidly with the explosion of an atomic bomb than it is in the laboratory. Second, due to smoke obscuration the animals in the field actually received a smaller percentage of the total energy delivered than they did in the laboratory. Third, the blast wave following the explosion tended to extinguish flames and remove char, whereas no such wave was present in the laboratory tests. Fourth, where the heat reached the fabric layer next to the skin, uniform drape (or spacing) provided additional protection in the field.

(1) In comparing field with laboratory results, consideration must be given to irradiance, which expresses the time-intensity of the thermal pulse ($cal/cm^2/sec$). At the highest calorie levels laboratory irradiances were much lower than field irradiances. The reason for this is that an atomic explosion delivers a high quantity of thermal energy per unit area in a much shorter time than the same quantity can be delivered over a practical exposure area (1.7 cm diam) with existing laboratory equipment. For example, approximately 2 sec are required to deliver 75 cal/cm^2 in the laboratory with the carbon arc operating at peak capacity, an irradiance of 37.5 $cal/cm^2/sec$. In the field this much energy was delivered at the forward stations in both Shots 9 and 10 in approximately 0.5 sec, an irradiance of 150 $cal/cm^2/sec$.

Irradiances have been varied within the limits possible in the laboratory, and it has been found that certain levels of thermal energy will produce a more serious lesion if applied slowly than if applied rapidly.(18) Beneath the HW assembly spaced 5 mm from the skin, for example, a 2+ burn was produced when a thermal energy of 17 cal/cm^2 was applied in 2 sec (8.5 $cal/cm^2/sec$) but no burn, or at the most a mild 1+ burn, resulted when the same energy was applied in 0.5 sec (34 $cal/cm^2/sec$). With lower irradiances the fabric may be scorched or charred but remain intact and thus act as a heat reservoir from which heat can subsequently be transmitted to the skin. With higher irradiances, laboratory results indicate that all or part of the thermal input may be dissipated by an endothermic decomposition of the fabric. In the field, especially at the closer stations where irradiances exceeded 35 $cal/cm^2/sec$, conditions were favorable for such dissipation of energy.

(2) Motion pictures of clothed animals, exposed to 50.0 and 33.5 cal/cm^2 on Shots 9 and 10 respectively, showed heavy clouds

of black smoke enveloping the animals within 120 ms of the explosion. There is reason to believe that, in view of the short time within which most of the radiant energy from the explosion was delivered, much of this energy was prevented from reaching the animals by this smoke. In the laboratory tests, because the exposure area was so much smaller and the time of energy application at the high calorie levels so much longer, smoke obscuration appears to be of little or no significance.

(3) The blast wave following the explosion, which has not been duplicated in laboratory applications of thermal energy, has two possible protective effects. First, it can be expected to extinguish flames induced by the radiation in assemblies not treated for fire resistance, thus removing a source of high heat. Although the blast wave may not actually extinguish the flame in all cases,* it can be expected in general to have this effect. Second, the blast wave would tend to remove any char which, if allowed to remain, would act as a heat reservoir and increase the likelihood of a severe burn.

(4) The drape of the uniform may have contributed to a reduction of thermal injury in the field, in the case of the two-layer Hot-Wet assemblies. Laboratory tests upon which estimates of protection in the field were based consisted of the application of energy to fabrics in tight contact with the animal's skin. Other tests on cotton fabrics have indicated that spacing the fabric away from the skin would increase the protection afforded. In the uniforms, although some fabric areas were in close skin contact, many were spaced away in normal drape. This fact undoubtedly gave the uniforms an additional protective value as compared to laboratory tests where fabrics were held in close skin contact.

4.2 THE ROLE OF THE FLAMEPROOFING TREATMENT

One of the major problems designated for study at UPSHOT-KNOTHOLE was to determine whether materials actually did flame under the conditions of the test and, if so, how much protection could be afforded by fire resistant treating the outer layer. The results of the test show conclusively that flaming and probably glow did occur in many instances. The principal value of the fire retardant used in these tests, brominated triallyl phosphate, lay in its prevention of these exothermic reactions. In some cases it also seemed to give additional protection against the primary thermal effects of the explosion, although in other cases the untreated fabrics gave better protection than the treated. The peculiar pebbly, blistered, weeping edema noted in these tests occurred only in pigs wearing the fire resistant uniforms.

---

*The occurrence of persistent flame type burns that require longer to produce (according to laboratory tests) than the blast arrival time may indicate that the blast wave does not always extinguish the flame. On the other hand such burns may have been induced by glow.

TABLE B.7 Percentage Destruction of Exposed Fabric Layers of Various Uniforms

Thermal Energy (cal/cm2)	HW		HWFR		HW 50/50		HWFR 50/50		T		TFR	
	Outer Layer	Second Layer	Outer Layer	Second Layer	Outer Layer	Second Layer	Outer Layer	Second Layer	Outer Layer	Second Layer	Outer Layer	Second Layer
					Shot 9							
75.0									95	30	95	0
									95	25	95	0
50.0	100	98	95	20								
	100	95	98	15								
41.0					98	15	98	0				
					98	2	95	0				
33.5	100	95			95	2	95	0				
29.5					90*	5	98	0				
21.5	98	30	90	2	98	0						
	98	10	90	0	95	0						
	95	40	95	0	95	0						
16.0	95	30	90	0	98							
	98	25	80	0	95							
	98	30	75	0	98							
12.5	98	15	75	0	85	1						
	95	10	70	0	95	0						
	100	60	70	0	98	1						
						Shot 10						
40.5					100	90	100	25				
33.5					98	60	98	5				
					98	30	98	15				
26.0	98	50	98	75	98	0	98	0	98	0		
	100	80	95	15	98	3	95	0	90	1		
17.5	98	5	95	5					98	0		
17.0	100	5	95	0					90	3		

*This animal had shifted in the holder.

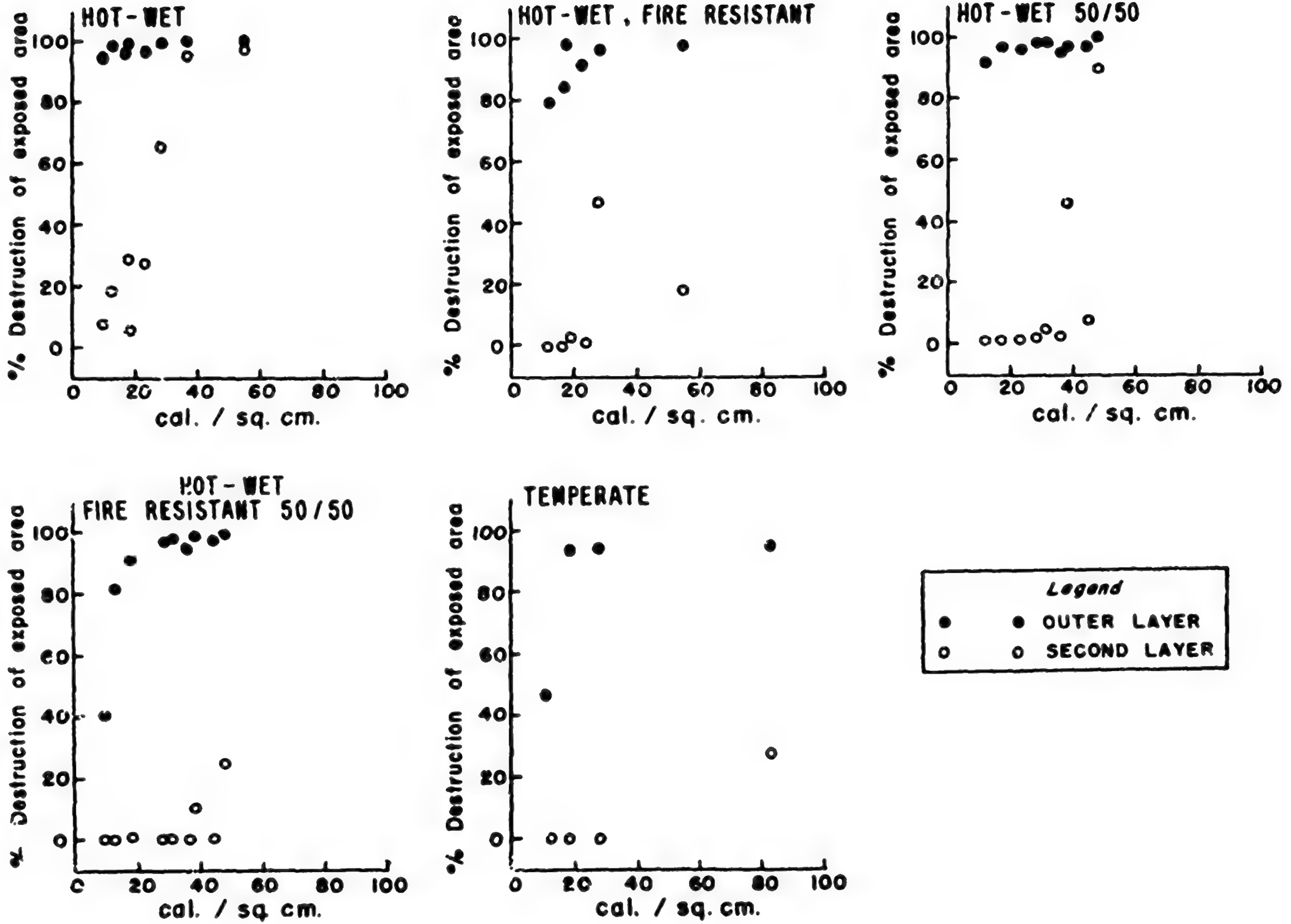

Fig. 3.5 Destruction of Outer and Second Layers of Pigs' Uniforms (Shots 9 and 10)

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No. 175 of 185 copies, Series A

OPERATION PLUMBBOB

NEVADA TEST SITE
MAY-OCTOBER 1957

Project 8.2

PREDICTION of THERMAL PROTECTION of UNIFORMS, and THERMAL EFFECTS on a STANDARD-REFERENCE MATERIAL (U)

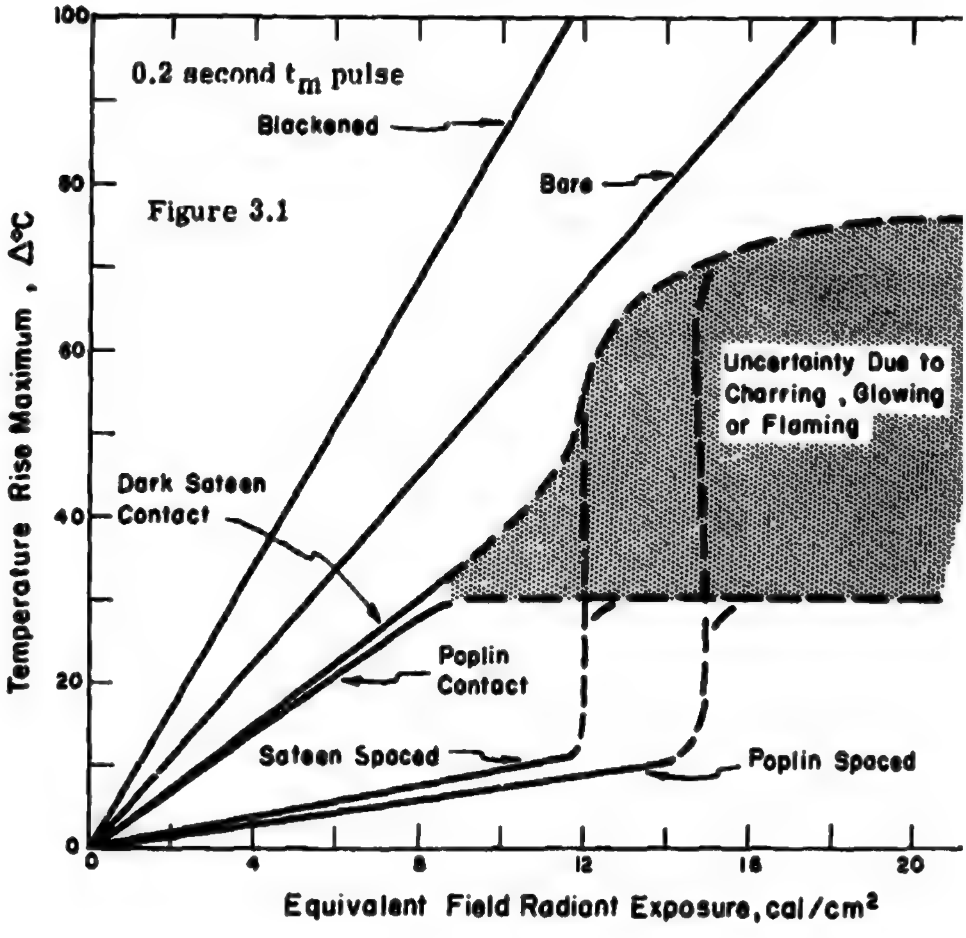
Issuance Date: May 2, 1960

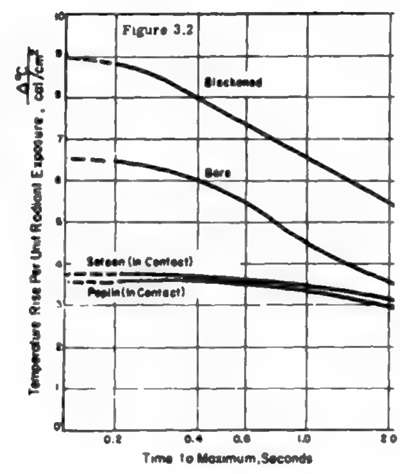
HEADQUARTERS FIELD COMMAND
DEFENSE ATOMIC SUPPORT AGENCY
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

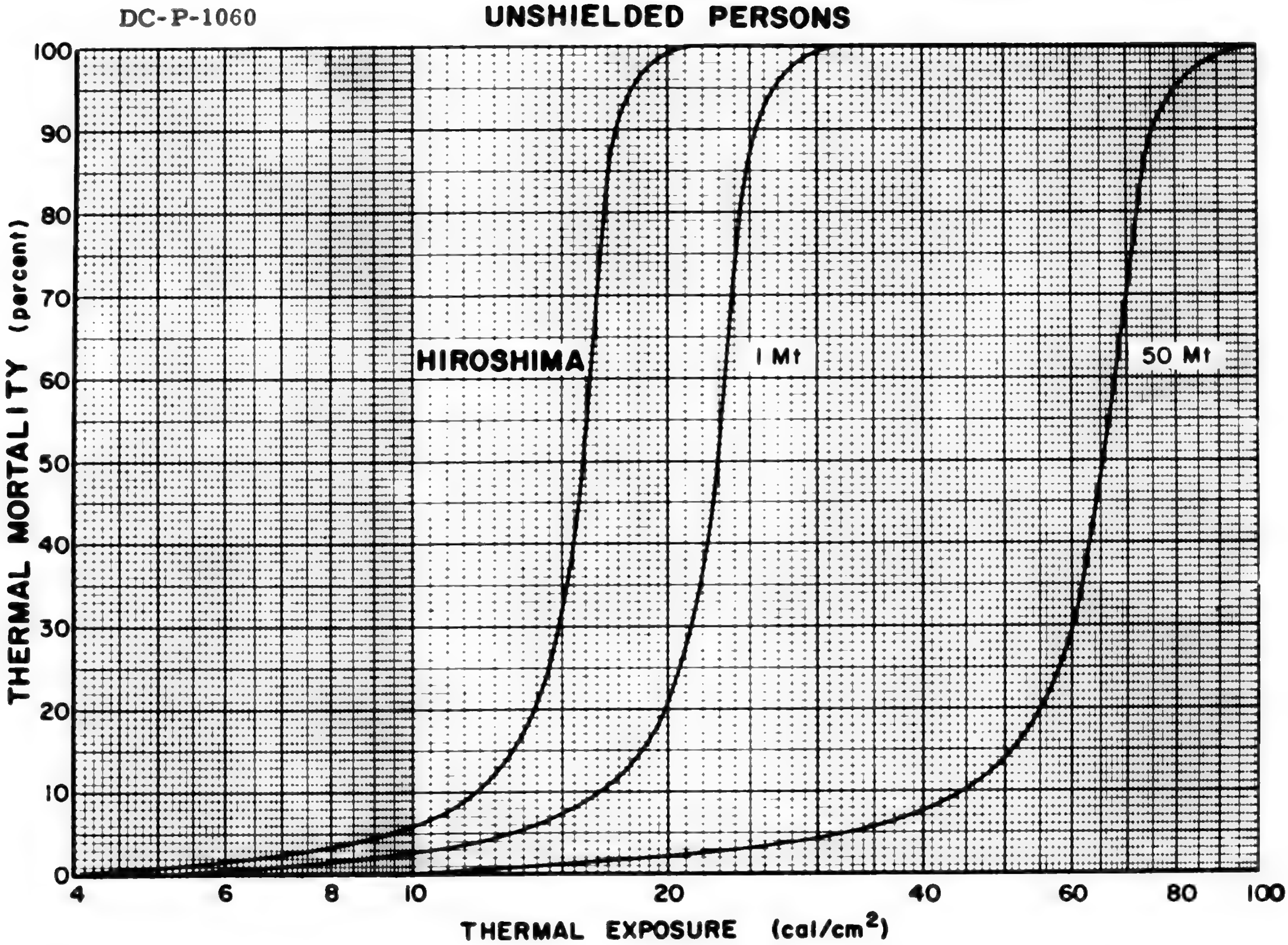
1.2.2 Comparison of Skin-Simulant Response and Burns to Pigs. The improved NML skin simulant, molded from silica-powder-filled urea formaldehyde, has the thermocouple embedded at a depth of 0.05 cm in order to give burn predictions based on maximum temperature attainment. The basic criterion is a rise of 25 C or more for a second-degree burn to human skin or for a 2+ mild burn to pig skin. This criterion is based on the assumption of (1) the equivalence of a minimal white burn on the rat skin (or a 2+ mild burn in pig skin) to a second-degree burn in human skin, (2) an initial skin temperature of 31 C, and (3) correspondence of the thermal properties of pig, rat, and human skin. The accuracy of such a burn prediction in terms of indicent radiant exposure is estimated to be ± 10 percent. A skin-simulant temperature rise of 20 C or greater is estimated to correspond to a first-degree human burn or a 1+ moderate pig skin burn, and a rise of 35 C is estimated for a third-degree human burn or a 3+ mild pig burn. The latter estimations, probably accurate to ± 20 percent, are based on pig-burn data obtained at the University of Rochester (Reference 6).

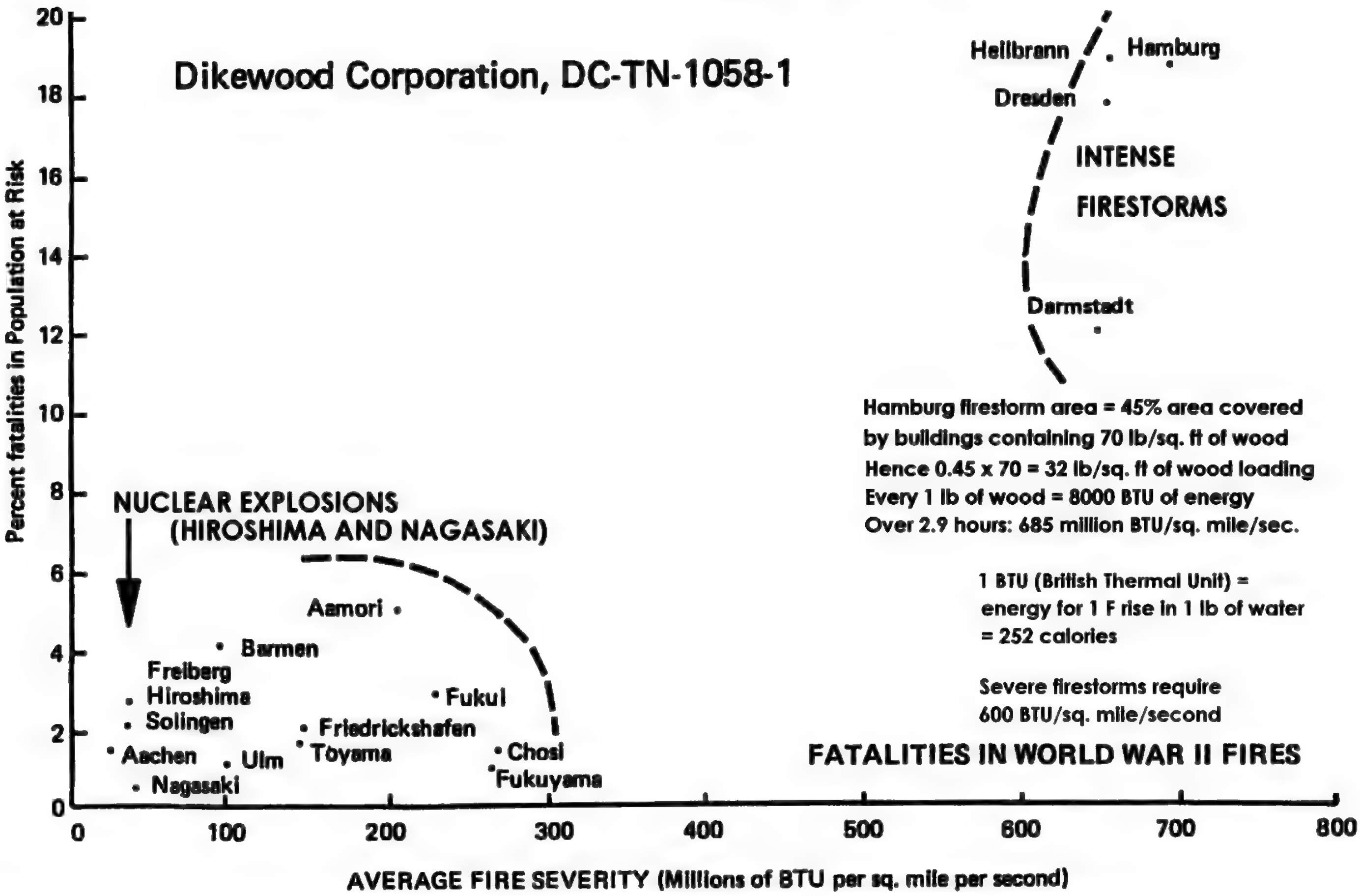
TABLE 2.1 RADIANT ABSORPTANCES OF SKIN SIMULANT AND STANDARD FABRICS

Specimen	Radiant Absorptance
Skin simulant, bare	0.72
Skin simulant, blackened	0.95
Poplin, Shade 116, 5-oz/yd^2	0.63
Sateen, gray, 9-oz/yd^2	0.91









T. E. Lommasson and J. A. Keller, A Macroscopic View of Fire Phenomenology and Mortality Prediction, Proceedings of the Tripartite Technical Cooperation Program, Mass Fire Research Symposium of the Defense Atomic Support Agency, The Dikewood Corporation; October, 1967.

EXPERIENCE OF GERMAN AND JAPANESE AIR RAIDS

Source: AD0642790, p. 8. Basic data:
Dirkwood DC-WP-1040-1, AD-827 029/0

City	Lives Lost	Percent of Population	Buildings Destroyed	Area Burned, sq mi
Tokyo	84,000	1.2	300,000	15.8 (total loss)
Hamburg	42,000	2.4	300,000	4.5 (total loss)
				12 (heavy damage)
Kassel	8,700	3.8	33,000	2.9 (total loss)
Darmstadt	8,100	7.4	22,000	1.5
Hiroshima	70,000*	28.0	68,000	4.4 (firestorm area)
Nagasaki	40,000*	17.0	21,000	0.049 (fire only)
				0.864 (fire and blast)

*Guest Korean workers, POWs, and military personnel excluded.

When water evaporates from the burned surface, cooling results and the body loses heat. The larger the burn wound, the more water loss and the more heat or energy loss.

How Can the Fluid and Heat Losses Be Diminished?

Think Plastic Wrap as Wound Dressing for Thermal Burns

ACEP (American College of Emergency Physicians) News
http://www.acep.org/content.aspx?id=40462

August 2008
By Patrice Wendling
Elsevier Global Medical News

CHICAGO - Ordinary household plastic wrap makes an excellent, biologically safe wound dressing for patients with thermal burns en route to the emergency department or burn unit.

The Burn Treatment Center at the University of Iowa Hospitals and Clinics, Iowa City, has advocated prehospital and first-aid use of ordinary plastic wrap or cling film on burn wounds for almost two decades with very positive results, Edwin Clopton, a paramedic and ED technician, explained during a poster session at the annual meeting of the American Burn Association.

"Virtually every ambulance in Iowa has a roll of plastic wrap in the back," Mr. Clopton said in an interview. "We just wanted to get the word out about the success we've had using plastic wrap for burn wounds," he said.

Dr. G. Patrick Kealey, newly appointed ABA president and director of emergency general surgery at the University of Iowa Hospital and Clinics, said in an interview that plastic wrap reduces pain, wound contamination, and fluid losses. Furthermore, it's inexpensive, widely available, nontoxic, and transparent, which allows for wound monitoring without dressing removal.

"I can't recall a single incident of its causing trouble for the patients," Dr. Kealey said. "We started using it as an answer to the problem of how to create a field dressing that met those criteria. I suppose that the use of plastic wrap has spread from here out to the rest of our referral base."

Although protocols vary between different localities, plastic wrap is typically used for partial- and full-thickness thermal burns, but not superficial or chemical burns. It is applied in a single layer directly to the wound surface without ointment or dressing under the plastic and then secured loosely with roller gauze, as needed.

Because plastic wrap is extruded at temperatures in excess of 150° C, it is sterile as manufactured and handled in such a way that there is minimal opportunity for contamination before it is unrolled for use, said Mr. Clopton of the emergency care unit at Mercy Hospital, Iowa City. However, it's best to unwind and discard the outermost layer of plastic from the roll to expose a clean surface.

UCRL-TR-231593

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Thermal Radiation from Nuclear Detonations in Urban Environments

R. E. Marrs, W. C. Moss, B. Whitlock

June 7, 2007

Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

6. L. Davisson and M. Dombroski, private communication; "Radiological and Nuclear Response and Recovery Workshop: Nuclear Weapon Effects in an Urban Environment 2007," M. Dombroski, B. Buddemeier, R. Wheeler, L. Davisson, T. Edmunds, L. Brandt, R. Allen, L. Klennert, and K. Law, UCRL-TR-XXXX (2007), in review.

Addendum No. 1

for

DNA 1240H-2, Part 2

HANDBOOK OF
UNDERWATER NUCLEAR EXPLOSIONS

21 January 1974

M. J. Dudash
DASIAC
General Electric Company–TEMPO
816 State Street
Santa Barbara, CA 93102

19 August 1973 CHAPTER 18

18.7 THERMAL AND NUCLEAR RADIATION EFFECTS ON SURFACE SHIP PERSONNEL

18.7.1 Casualty and Risk Criteria

Table 18-2

CDC NUCLEAR AND THERMAL RADIATION CRITERIA

New Thermal Radiation Criteria

Risk Criteria for Burns Under Summer Uniforms to Warned, Exposed Personnel

	% Incidence	Mechanism	10KT cal/cm^2	100KT cal/cm^2	1000KT cal/cm^2
Negligible	2.5	1° burn	3.1	4.2	5.8
Moderate	5	1° burn	3.7	5.0	6.8
Emergency	5	2° burn	6.3	8.8	12

	Casualties due to 2nd Degree Burns			
Time to Ineffectiveness	% Incidence	10KT cal/cm^2	100KT cal/cm^2	1000KT cal/cm^2
24. hr	50	38	53	73

Personnel Risk and Casualty Criteria for Nuclear Weapons Effects
ACN 4260, U. S. Army Combat Developments Command Institute of Nuclear Studies, August 1971

EFFECTS OF SPECTRAL DISTRIBUTION OF RADIANT ENERGY ON CUTANEOUS BURN PRODUCTION IN MAN AND THE RAT

Research and Development Technical Report USNRDL-TR-46
NM 006-015

25 April 1955

by

E. L. Alpen
C.P. Butler
S.B. Martin
A.K. Davis

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
San Francisco 24, California

For human skin the reflectivities and critical energies for production of a standard burn are the following:

filter "A", $\lambda_{max} = 0.42\mu$, $r = 24.4 \pm 3.5$ per cent, $Q = 3.20 \pm 0.37$ cal/cm^2;

filter "B", $\lambda_{max} = 0.55\mu$, $r = 40.9 \pm 3.8$ per cent, $Q = 3.25 \pm 0.28$ cal/cm^2;

filter "C", $\lambda_{max} = 0.65\mu$, $r = 56.9 \pm 2.5$ per cent, $Q = 9.9 \pm 2.1$ cal/cm^2;

filter "D", $\lambda_{max} = 0.85\mu$, $r = 53.4 \pm 2.2$ per cent, $Q = 14.0 \pm 1.1$ cal/cm^2;

filter "F", $\lambda_{max} = 1.7\mu$, $r = 17 \pm 0.60$ per cent, $Q = 2.50$ cal/cm^2 (approx.).

The ranges shown are standard deviations.

The significance of the optical properties of skin has been discussed and the property of the high transmission of skin in the region 0.7 to 1.0 has been presented.

SUMMARY

The Problem

How does the critical energy for the production of standard burns in both rats and humans vary with the wavelength of radiant energy?

Findings

The critical radiant energy, corrected for spectral reflectance, required for production of standard burns in both rat and human skin varies as much as 4-fold depending on the wavelength.

Proceedings of a Workshop

13 - 14 March 1968

Sponsored

by

The Committee on Fire Research
Division of Engineering
National Research Council

and the

Office of Civil Defense, Department of the Army

Published

by

National Academy of Sciences
Washington, D.C.
1969

Dr. Edward L. Alpen (U. S. Naval Radiological Defense Laboratory): About this question of the spectral dependence of radiant energy, I think Dr. Haynes may have given you the impression that white light does the trick. There is later work which tends to refute that. The work done at Virginia used cut-off filters. The effectiveness of all energy above a certain wave length or below a certain wave length was measured. At the upper end the most effective and the least effective were mixed together and made it appear that infrared was not too good in producing burns. When you subdivide the spectrum, the most effective energy in producing a flash burn is the infrared above about 1.2 microns.

The importance of this, and the only reason I make an issue of it, is that a very important source of flash burn, both in civilian life and under wartime disaster conditions, is radiant energy burns from flaming sources. We have done a great deal of research on this subject for the U. S. Forest Service, because radiant energy burns are important in forest fires.

Energy in the wave lengths of 0.6 to 0.8 micron is about one-eighth as destructive as the rest of the spectrum. But long wave length radiation above one micron is extremely destructive, and the most effective of all.

Dr. Alpen: Anything that shields out radiation above one micron is extremely effective in preventing burns to the skin.

RESEARCH TRIANGLE INSTITUTE
Durham, North Carolina

Final Report R-85-1

CRASH CIVIL DEFENSE PROGRAM STUDY

by

K. E. Willis
E. R. Brooks
L. J. Dow

April 30, 1963

Prepared for

OFFICE OF CIVIL DEFENSE
UNITED STATES DEPARTMENT OF DEFENSE

Feasibility

In the typical household, some materials will generally be available for covering windows against thermal radiation. One half roll of aluminum foil would cover about 25 ft^2 and would provide very effective covering for 1 to 2 windows (those most likely to face the blast). Sufficient quantities of either light colored paint, Bon Ami, or whiting would be available in most households to cover windows. Aluminum screens attenuate from 30 - 50% of the thermal radiation and hence screens should be closed or installed.

The amount of water per square foot required to dissipate 25 cal/cm^2 of thermal radiation can quickly be calculated from the heat of vaporization of water (580 cal/gm). Allowing 90% losses due to absorption or spillage, one gallon of water is sufficient to wet 10 ft^2 of material so that it can withstand 25 cal/cm^2 of direct thermal radiation (i.e., the radiation is normal to the material surface at all points). Since the average daily water consumption per service (Reference 3) is about 700 gallons, it is apparent that the wetting of interior flammables (piled up curtains, furniture, etc.) is feasible in most cases when used in conjunction with the other measures.

3. <u>Statistical Abstracts of the United States</u>. Washington: U. S. Government Printing Office, 1962.

HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

The probable fire situation in a British city

35 Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire.

From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum —this proportion being more easily absorbed by the atmosphere.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.

ADA383988

November 1963
Second printing May 1964

Unclassified Version

SURVEY OF THE THERMAL THREAT OF NUCLEAR WEAPONS

Prepared for:

OFFICE OF CIVIL DEFENSE
DEPARTMENT OF DEFENSE
WASHINGTON 25, D.C.

By: Jack C. Rogers and T. Miller

SRI Project No. IMU-4021

Approved:

Robert A. Harker

ROBERT A. HARKER, DIRECTOR
MANAGEMENT SCIENCES DIVISION

OCD REVIEW NOTICE

This report represents the authors' views, which in general are in harmony with the technical criteria of the Office of Civil Defense. However, a preliminary evaluation by OCD indicates the need for further evaluation of the fire threat of nuclear weapons and formulation of promising research and action programs.

NOTE: discrepancies are due to HUMIDITY differences. ENCORE nuclear test (Nevada desert) humidity was ONLY 19%

Table B-VII

COMPARISON OF ESTIMATES FOR IGNITION ENERGY REQUIREMENTS
(10 mt)

Glasstone (1962) The Effects of Nuclear Weapons		Martin, et al. (1959) Naval Radiological Defense Laboratory		
Material	Cal/cm^2 for Ignition	Material	Cal/cm^2 for Ignition	Ratio of NRDL to ENW
Cotton auto seat upholstery, green, brown, white	16	Heavy cotton draperies, dark color	28	1.75
Wool pile chair upholstery, wine	35 (not sustained)	Wool pile chair upholstery, dark color	25	0.7
Newspaper, single sheet	6	Newspaper, medium printed	40	6.7
		Newspaper, dark areas	30	5.
Kraft paper carton, flat side exposed, used, brown	15	Corrugated Kraft board	40	2.6
Deciduous leaves	12	Walnut leaves	54	4.5
		Beech leaves	36	3.
Coarse grass	16	Harding grass	44	2.7
Ponderosa pine needles, brown	18	Pine needles	50	2.7

Sources: Martin, et al. (1959) and Glasstone (1962).

Martin, S. B., On Predicting the Ignition Susceptibility of Typical Kindling Fuels to Ignition by the Thermal Radiation from Nuclear Detonations, Tech. Report 367, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif., April 1959. (U)

A SURVEY OF THE WEAPONS AND HAZARDS WHICH MAY FACE THE PEOPLE OF THE UNITED STATES IN WARTIME

Harold L. Brode

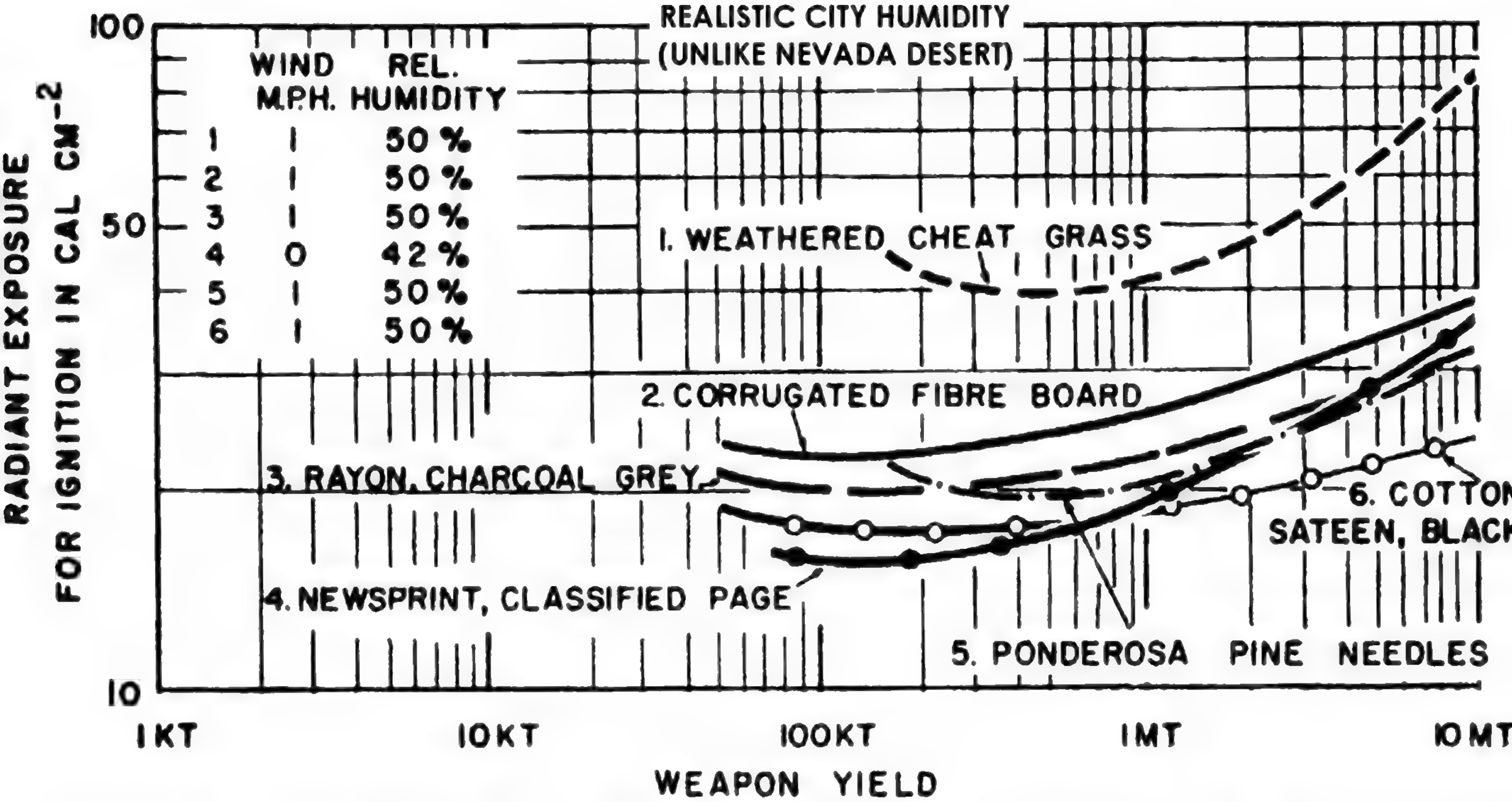
P-3170

June 1965

Most exposed surfaces in the city are non-combustible and much of the remainder is not ignitable by thermal flash. Although many fires could simultaneously start wherever building interiors are illuminated by the bomb thermal energy, they are not likely to be immediately beyond control, and will often go out unattended as they exhaust the available fuel (as in trash barrels or isolated wood piles or even pieces of paper on tables or floors).

Hanging non-flammable shields over window openings and removing likely fuels from exposed positions could also help.

RAND CORPORATION



"TECHNICAL OBJECTIVE AW-7, CRITICAL RADIANT EXPOSURES FOR PERSISTENT IGNITION", JULY 1960, J. BRACCIAVENTI & F. DEBOLD AD-249476; DASA-1194

UCRL-TR-231593

Thermal radiation from nuclear detonations in urban environments

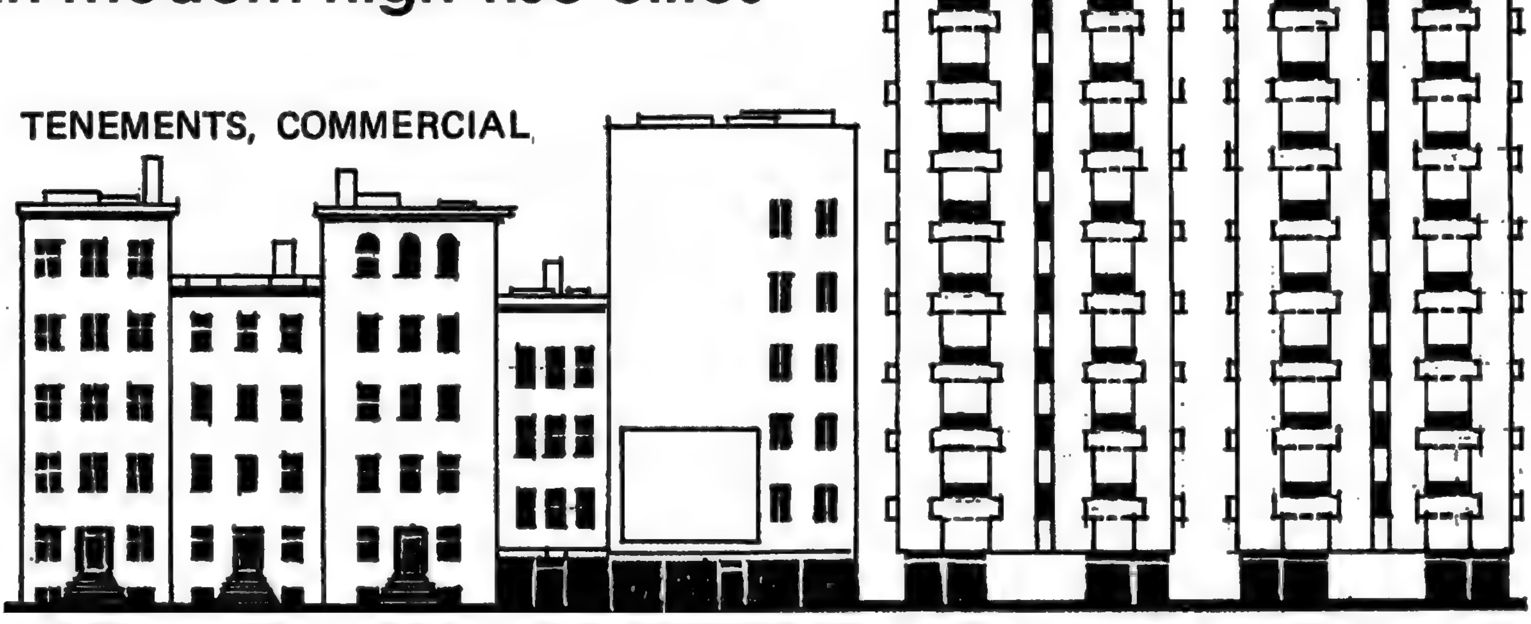
LAWRENCE LIVERMORE NATIONAL LABORATORY

June 7, 2007

Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

Thermal radiation shadowing in modern high-rise cities



HOME OFFICE

CD/SA 121

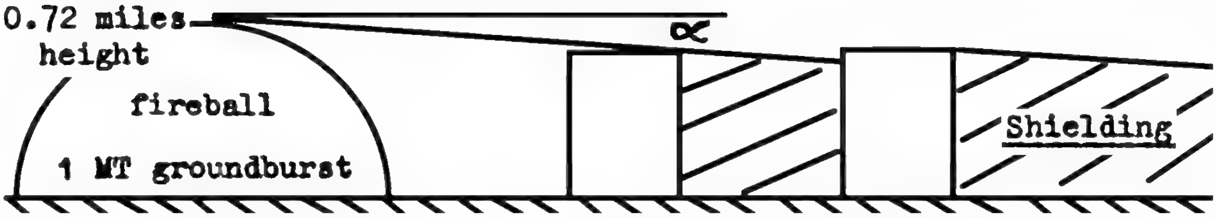
SCIENTIFIC ADVISER'S BRANCH

(Paper at Tripartite Thermal Effects Symposium, Dorking, October 1964)

IGNITION AND FIRE SPREAD IN URBAN AREAS FOLLOWING A NUCLEAR ATTACK

G. R. Stanbury

INITIAL FIRE INCIDENCE



Thermal pulse precedes the blast wave

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height we take the average depth of a floor to be 10 ft.

Effect of Shielding: Estimation of the number of exposed floors

Distance from explosion miles	Angle of arrival α^{o}	Width of street (units of 10 ft.) 2	3	4	5	6	7	8
3	13½	.5	.5	1	1	1.5	1.5	2
4	10	.5	.5	.5	1	1	1.5	1.5
5	8	.5	.5	.5	.5	1	1	1

SPREAD OF FIRE

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs

Number of fires started per square mile in the fire-storm raid on Hamburg, 27th/28th July, 1943

102 tons H.E.	48 tons, 4 lb. magnesium	40 tons, 30 lb. gel.
100 fires	27,000 bombs	3,000 bombs
	8,000 on buildings	900 on buildings
	1,600 fires	800 fires
2,500 fires in 6,000 buildings		

However, the important thing to note is that the total number of fires started in each square mile (2,500) was nearly half that of the total number of buildings; in other words, almost every other building was set on fire

When the figure of 1 in 2 for the German fire storms is compared with the figures for initial fire incidence of $\sim$ 1 in 15 to 30 obtained in the Birmingham and Liverpool studies it can only be concluded that a nuclear explosion could not possibly produce a fire storm.

SECONDARY FIRES FROM BLAST DAMAGE IN LONDON

Fire situation from 1,499 fly bombs in the built-up part of the London Region

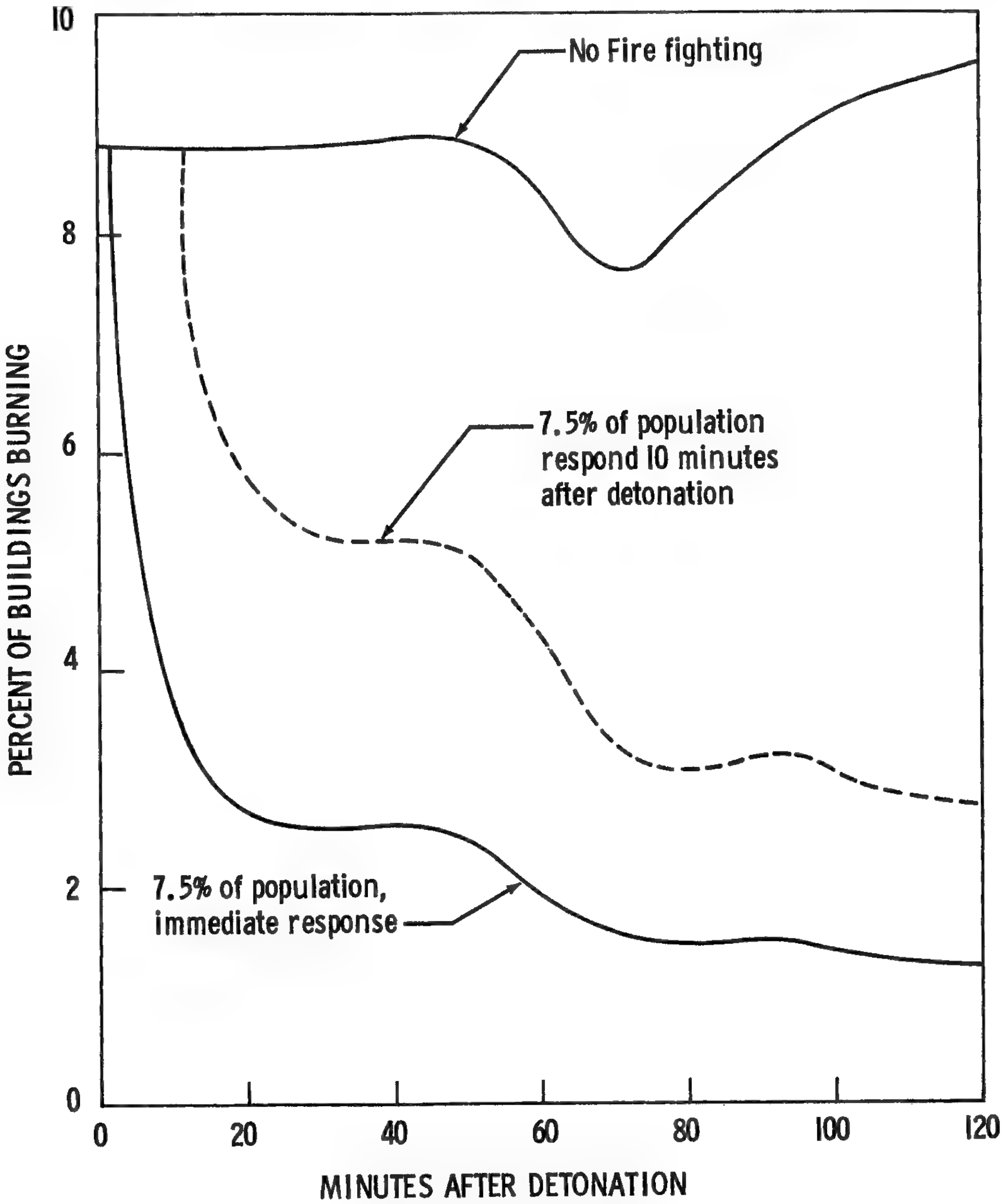
(Fires from 1 ton TNT V1 cruise missiles, 1944)

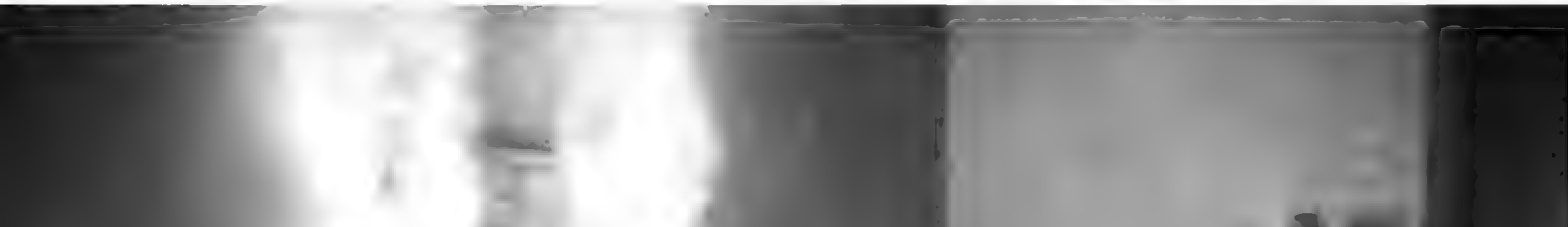
	Number of fly bombs	Fly Bombs Caused				
		No fire	Small fire	Medium fire	Serious fire	Major fire
Grand Totals	1,499	804	609	75	7	4

The large proportion started no fires at all even in the most heavily built-up areas.

All these fly bombs fell in the summer months of 1944 which were unusually dry. In winter in this country in residential areas there are many open fires which may provide extra sources of ignition. The domestic occupancy is a low fire risk however, and as the proportion of such property in the important City and West End areas is small this should not introduce any serious error. Moreover, in winter, the high atmospheric humidity and the correspondingly high moisture content of timber would tend to retard or even prevent the growth of fire.

Takata, A.N., Mathematical Modeling of Fire Defenses, IITRI, March 1970, AD 705 388.





Folded newspapers may not take fire, but loosely crumpled ones will. The answer? Get rid of trash.

A wet mop or broom will snuff out small fires. So will a burlap bag or a small rug soaked in water.

Buckets of water and sand are essential.

Water is an effective fire fighting agent because it smothers and cools at the same time.

FIRE-BOMBS rained on London

They did not all fall on roads

THE LUFTWAFFE SOUGHT A KNOCK-OUT BLOW. The first impact of the attack fell on the docks. The great day raid of 7th September, 1940, which was continued throughout the night and renewed on many nights after, left miles of fires blazing along either bank of the Thames. This is St. Katherine's Dock on the night of 11th September.

Amended Reprint
June, 1940

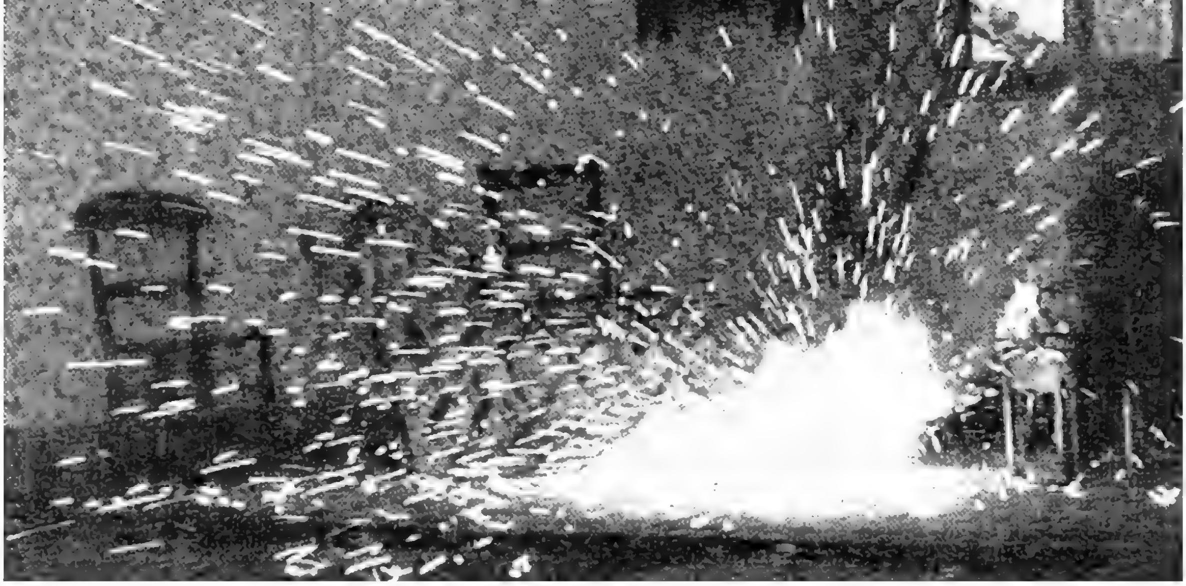
Air Raid Precautions
HANDBOOK No. 9

(*1st edition*)

INCENDIARY BOMBS AND FIRE PRECAUTIONS

Issued by the
Ministry of Home Security

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE



KILO MAGNESIUM INCENDIARY BOMB 15 SECONDS AFTER IGNITION.

45 SECONDS

FIRE CONTROLLED BY WATER

Clothing on fire.

Never allow a person whose clothes are on fire to remain standing for a moment. Fatalities nearly always arise from shock of burning about the face and head. If the person starts to run, trip him up at once. Roll him on the floor or in a coat or blanket if you have one handy. If your own clothes catch fire, clap your hand over your mouth, and lie down and roll.

Fig. 1—Typical Kilo Magnesium Incendiary Bomb.

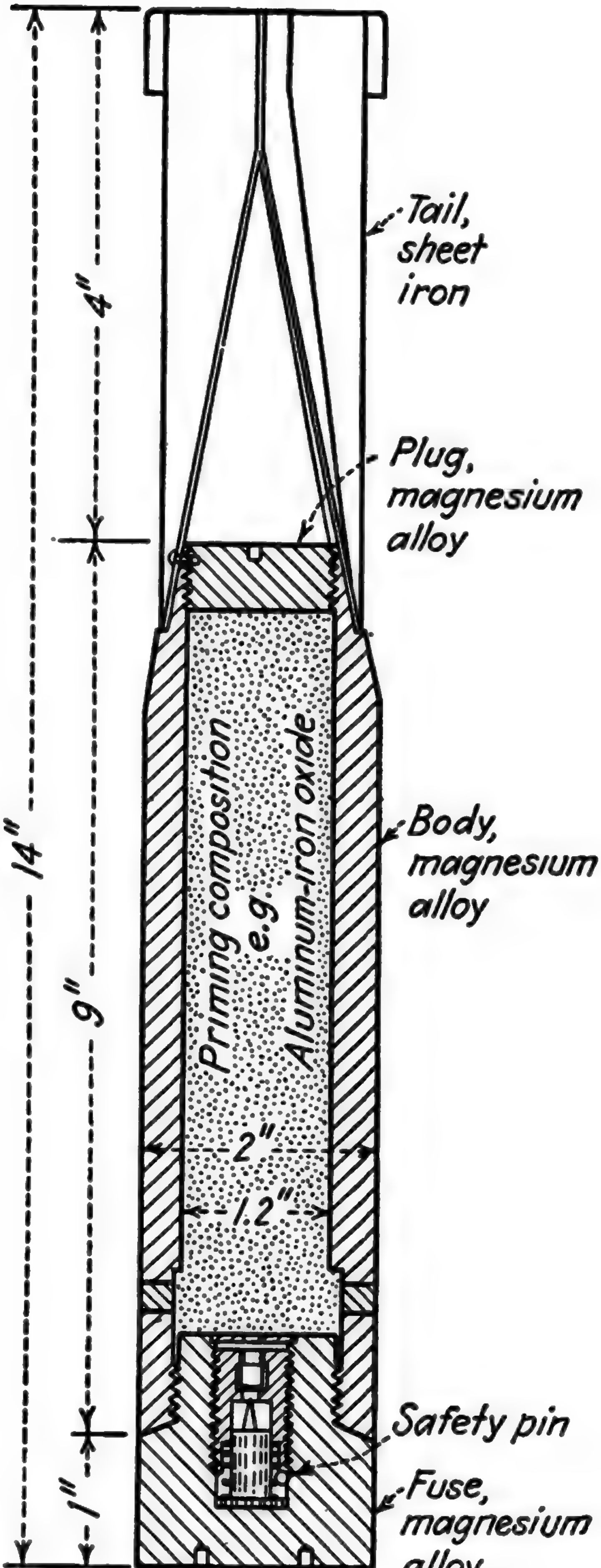


Fig. 2—Typical Kilo Magnesium Incendiary Bomb. Sectional Drawing.

Restricted **For Official Use**

CIVIL DEFENCE

TRAINING PAMPHLET NO. 2
(3rd Edition)

OBJECTS DROPPED FROM THE AIR

Issued by the Ministry of Home Security

LONDON
HIS MAJESTY'S STATIONERY OFFICE
1944

Price 6d. net

Copies will be sold only on written application by a Clerk to a local authority, a Chief Constable, a principal of a public utility company, or by County Secretaries of the St. John Ambulance Brigade, British Red Cross Society, and St. Andrew's Ambulance Association to H.M. STATIONERY OFFICE at any of the following addresses: York House, Kingsway, London, W.C.2; 13a Castle Street, Edinburgh; 39-41 King Street, Manchester 2; 1 St. Andrew's Crescent, Cardiff; or 80 Chichester Street, Belfast.

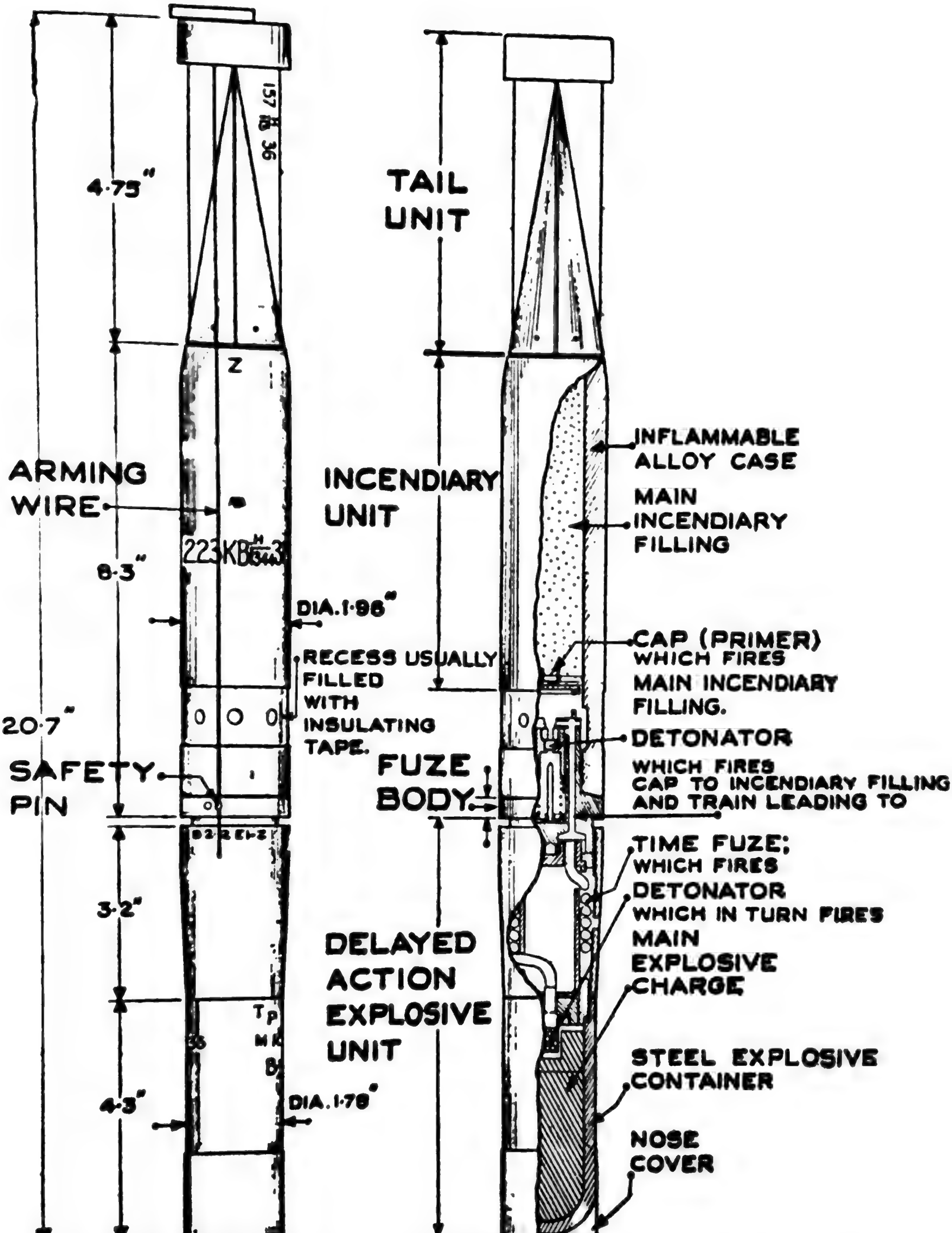


FIGURE 12A.—GERMAN INCENDIARY BOMB WITH EXPLOSIVE NOSE

DOMESTIC NUCLEAR SHELTERS

TECHNICAL GUIDANCE

To obtain some protection from the heat it is necessary to move out of the direct path of the rays from the fireball; any kind of shade will be of some value.

A fire-storm occurred only in an area of several square miles, heavily built up with buildings containing plenty of combustible material and where at least every other building in the area had been set alight. It is not considered that the initial density of fires, equivalent to one in every other building, would be caused by a nuclear explosion over a British city. Studies have shown that due to shielding, a much smaller proportion of buildings than this would be exposed to the heat flash. Moreover, the buildings in the centres of most British cities are now more fire-resistant and more widely spaced than they were 30 to 40 years ago. This low risk of fire-storms would be reduced still further by the control of small initial and secondary fires.

A HOME OFFICE GUIDE

P-3026

FIREBALL PHENOMENOLOGY

Harold L. Brode

The RAND Corporation, Santa Monica, California

This paper was prepared for presentation at The Tripartite Technical Cooperation Panel Meeting, Panel N3, held at the Joint Fire Service College, Dorking, England, 5-9 October 1964. The papers are to be published by Defense Atomic Support Agency.

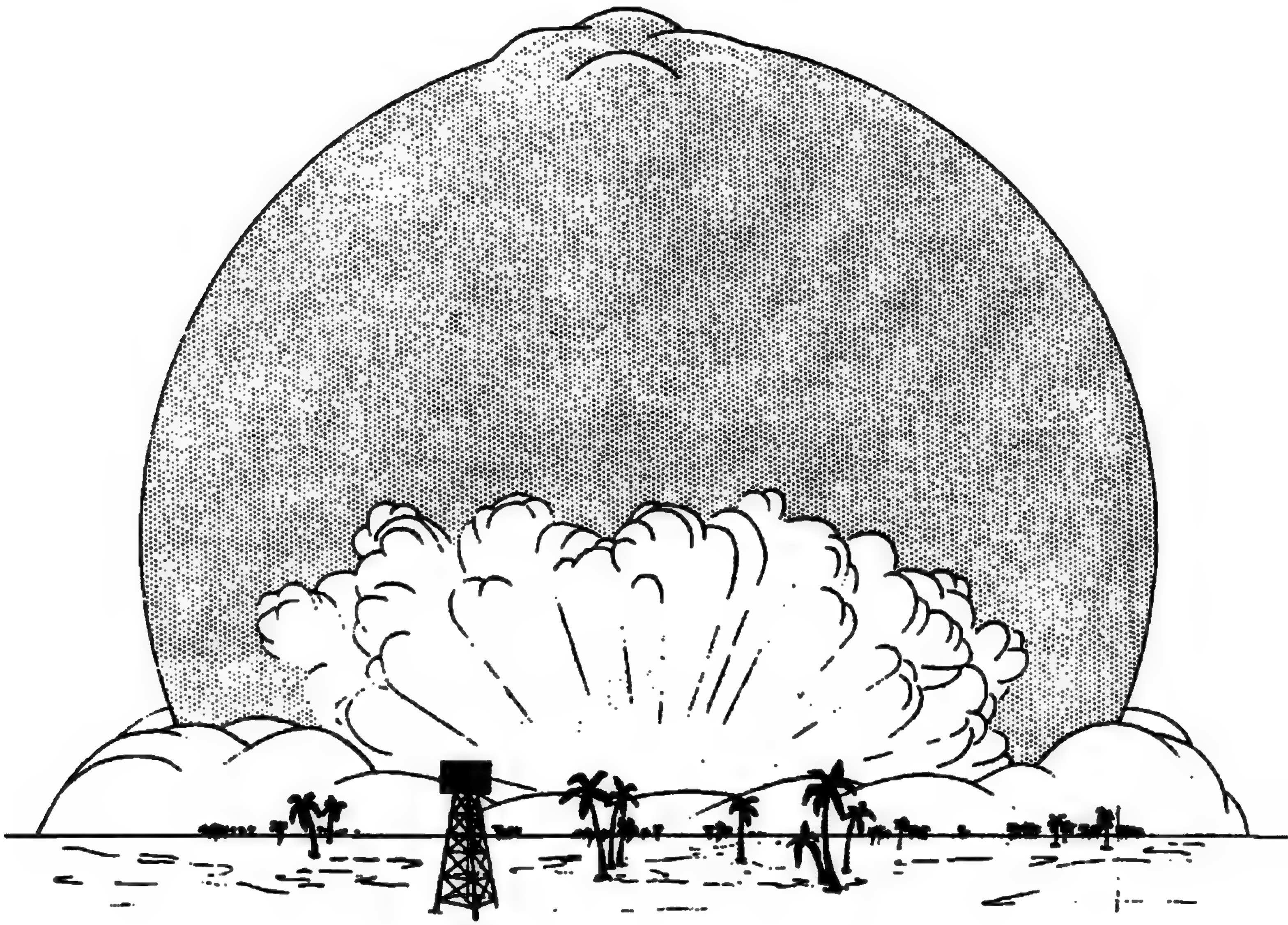
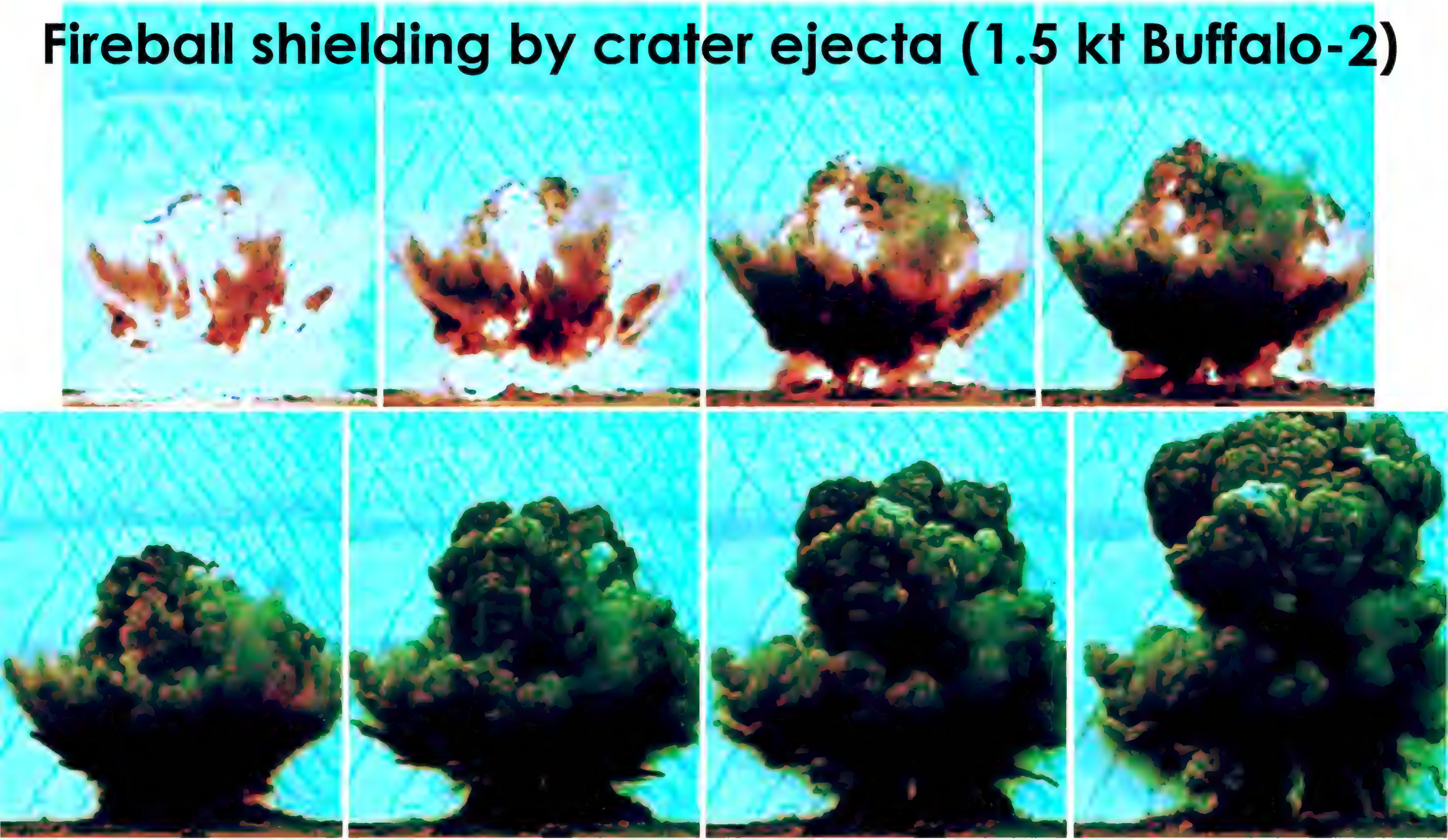
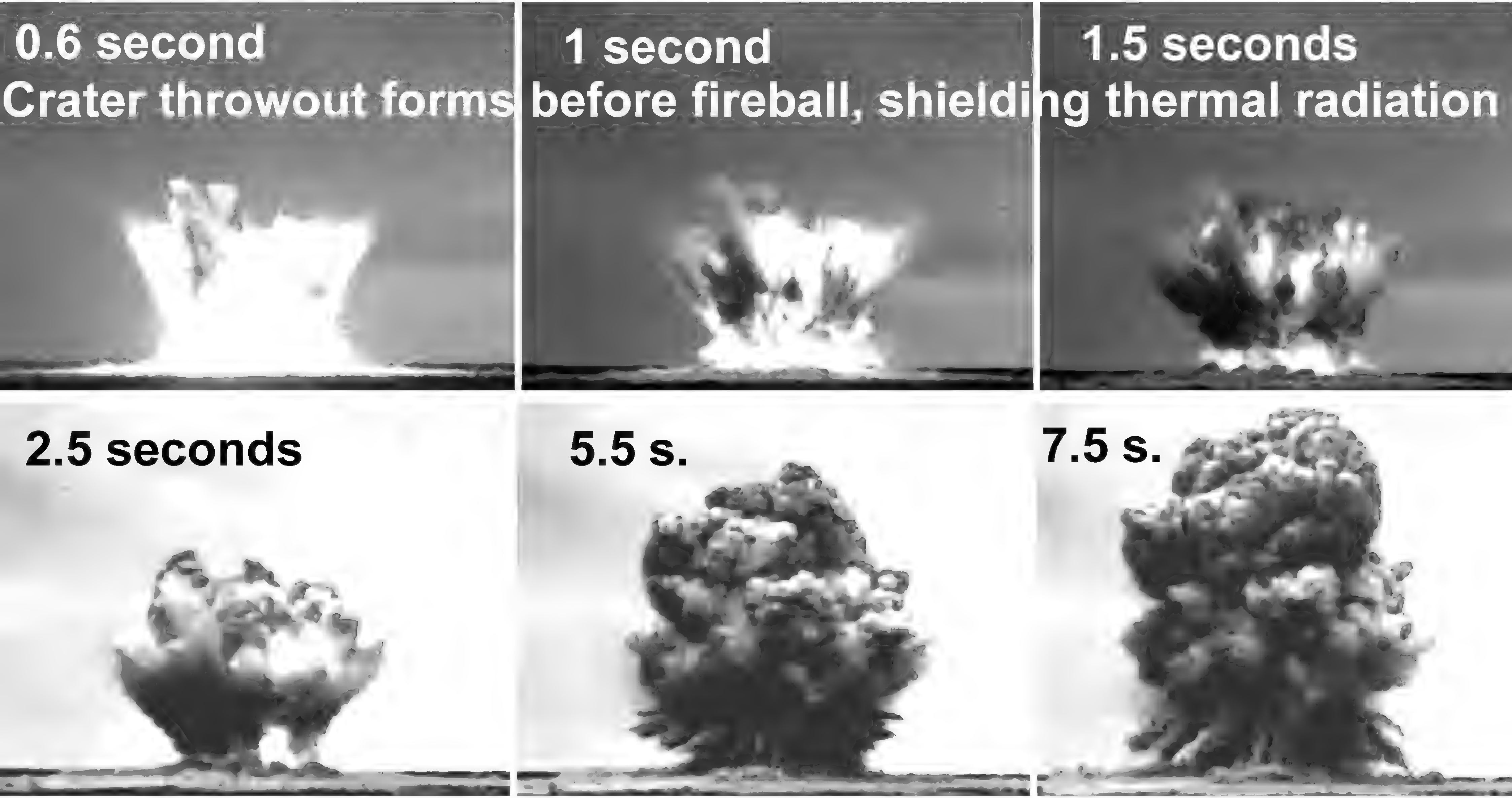


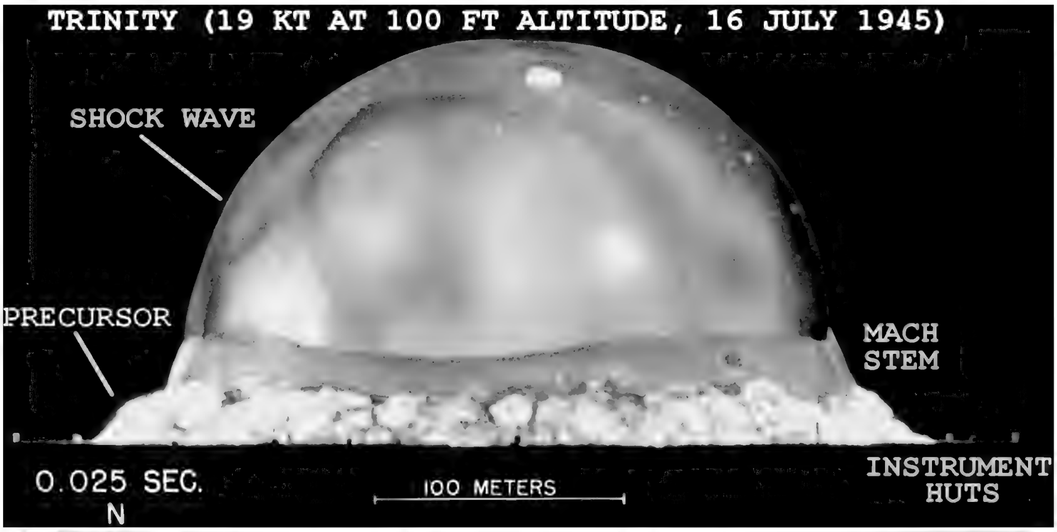
Fig. 20—Surface burst features influencing thermal radiation

Fireball shielding by crater ejecta (1.5 kt Buffalo-2)





Afterwinds immediately suck in base surge dust from throwout


TRINITY (19 KT AT 100 FT ALTITUDE, 16 JULY 1945)
SHOCK WAVE
PRECURSOR
MACH STEM
0.025 SEC.
N
100 METERS
INSTRUMENT HUTS


PRECURSOR DUST CLOUD ABSORBS FIREBALL BASE HEAT FLASH
1.0 SEC.
N
100 METERS


TOWER BASE, 1.4 R/HOUR
11 SEPTEMBER 1945

~~CONFIDENTIAL~~

DEPARTMENT OF THE ARMY TECHNICAL MANUAL
DEPARTMENT OF THE NAVY
DEPARTMENT OF THE AIR FORCE
MARINE CORPS PUBLICATIONS

TM 23-200
OPNAV INSTRUCTION 03400.1B
AFL 136-1
NAVMC 1104 REV

CAPABILITIES OF ATOMIC WEAPONS (U)

Prepared by
Armed Forces Special Weapons Project

DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE

REVISED EDITION NOVEMBER 1957

~~CONFIDENTIAL~~

Personnel in structures. A major cause of personnel casualties in cities is structural collapse and damage. The number of casualties in a given situation may be reasonably estimated if the structural damage is known. Table 6–1 shows estimates of casualty production in two types of buildings for several damage levels. Data from Section VII may be used to predict the ranges at which specified structural damage occurs. Demolition of a brick house is expected to result in approximately 25 percent mortality, with 20 percent serious injury and 10 percent light injury. On the order of 60 percent of the survivors must be extricated by rescue squads. Without rescue they may become fire or asphyxiation casualties, or in some cases be subjected to lethal doses of residual radiation. Reinforced concrete structures, though much more resistant to blast forces, produce almost 100 percent mortality on collapse. The figures of table 6–1 for brick homes are based on data from British World War II experience. It may be assumed that these predictions are reasonably reliable for those cases where the population is in a general state of expectancy of being subjected to bombing and that most personnel have selected the safest places in the buildings as a result of specific air raid warnings. For cases of no prewarning or preparation, the number of casualties is expected to be considerably higher.

6–2

Glass breakage extends to considerably greater ranges than almost any other structural damage, and may be expected to produce large numbers of casualties at ranges where personnel are relatively safe from other effects, particularly for an unwarned population.

Table 6–1. Estimated Casualty Production in Structures for Various Degrees of Structural Damage

	Killed outright	Serious injury (hospitalization)	Light injury (No hospitalization)
1–2 story brick homes (high explosive data):	*Percent*	*Percent*	*Percent*
Severe damage	25	20	10
Moderate damage	<5	10	5
Light damage	------	<5	<5

Note. These percentages do not include the casualties which may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentage of casualties expected at the maximum range where the specified structural damage occurs.

Personnel in a prone position are less likely to be struck by flying missiles than those who remain standing.

6–3

Table 6–2. Critical Radiant Exposures for Burns Under Clothing

(Expressed in cal/cm² incident on outer surface of cloth)

Clothing	Burn	1 KT	100 KT	10 MT
Summer Uniform	1°	8	11	14
(2 layers)	2°	20	25	35
Winter Uniform	1°	60	80	100
(4 layers)	2°	70	90	120

6–4

FIGURE 2-6 GROWTH OF THE MACH STEM

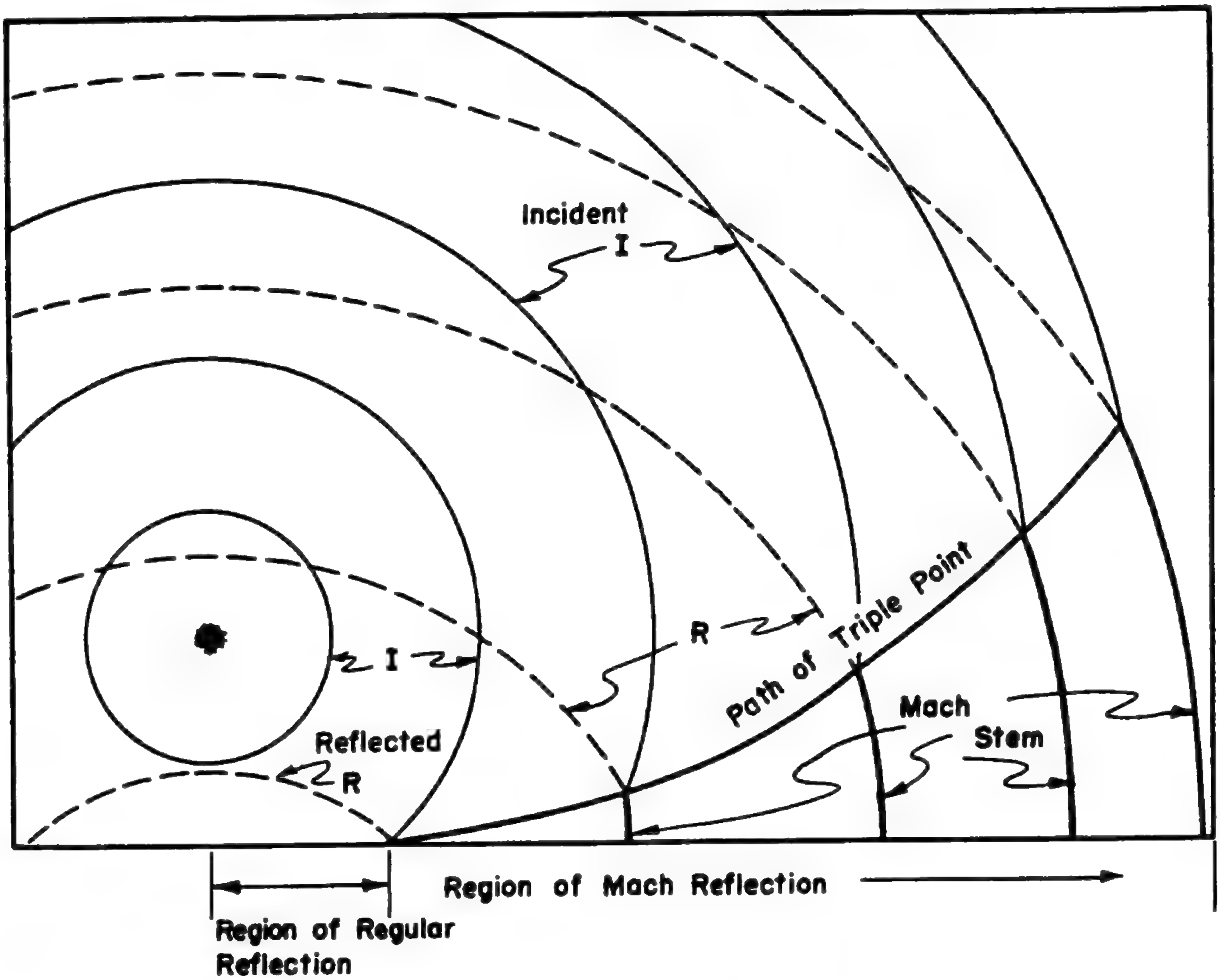
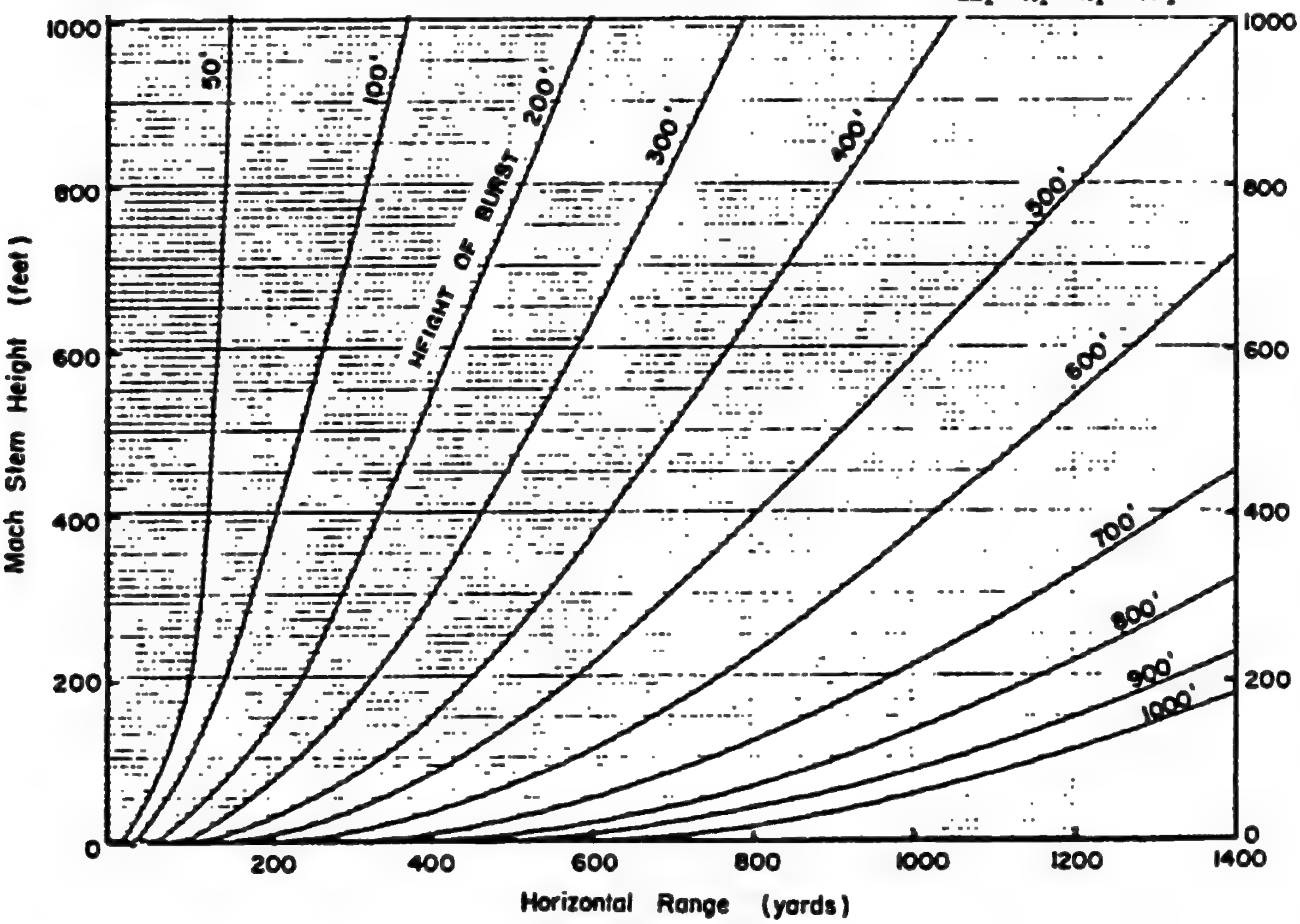


FIGURE 2-7 MACH STEM HEIGHT (1 KT) $\frac{H_1}{H_2}=\frac{h_1}{h_2}=\frac{d_1}{d_2}=\frac{W_1^{1/3}}{W_2^{1/3}}$



SECTION III
THERMAL RADIATION PHENOMENA

3.1 General

For a surface burst having the same yield as an air burst, the presence of the earth's surface results in a reduced thermal radiation emission and a cooler fireball when viewed from that surface. This is due primarily to heat transfer to the soil or water, the distortion of the fireball by the reflected shock wave, and the partial obscuration of the fireball by dirt and dust (or water) thrown up by the blast wave.

~~CONFIDENTIAL~~ 3-1

Measurements from the ground of the total thermal energy from surface bursts, although not as extensive as those for air bursts, indicate that the thermal yield is a little less than half that from equivalent air bursts. For a surface burst the thermal yield is assumed to be one-seventh of the total yield.

3-2 ~~CONFIDENTIAL~~

3.3 Radiant Exposure vs. Slant Range

a. Spectral. Characteristics. At distances of operational interest, the spectral (wavelength) distribution of the incident thermal radiation, integrated with respect to time, resembles very closely the spectral distribution of sunlight. For each, slightly less than one-half of the radiation occurs in the visible region of the spectrum, approximately one-half occurs in the infrared region and a very small fraction (rarely greater than 10 percent) lies in the ultraviolet region of the spectrum. The color temperature of the sun and an air burst are both about 6,000° K. A surface burst, as viewed by a ground observer, contains a higher proportion of infrared radiation and a smaller proportion of visible radiation than the air burst, with almost no radiation in the ultraviolet region. The color temperature for a surface burst is about 3,000° K. A surface burst viewed from the air may exhibit a spectrum more nearly like an air burst.

$$Q=\frac{3.16\times 10^6\ W\ (\overline{T})}{D^2}\ \text{cal/sq cm (air burst).}$$

and

$$Q=\frac{1.35\times 10^6\ W\ (\overline{T})}{D^2}\ \text{cal/sq cm (surface burst).}$$

where Q=radiant exposure (cal/sq cm)
$\overline{T}$=atmospheric transmissivity
W=weapon yield (KT)
D=slant range (yds).

~~CONFIDENTIAL~~ 3-3

The differences between the air burst and surface burst curves are caused by the difference in apparent radiating temperatures (when viewed from the ground) and the difference in geometrical configuration of the two types of burst.

50 mile visibility and 5 gm/m³ water vapor.
10 mile visibility and 10 gm/m³ water vapor.

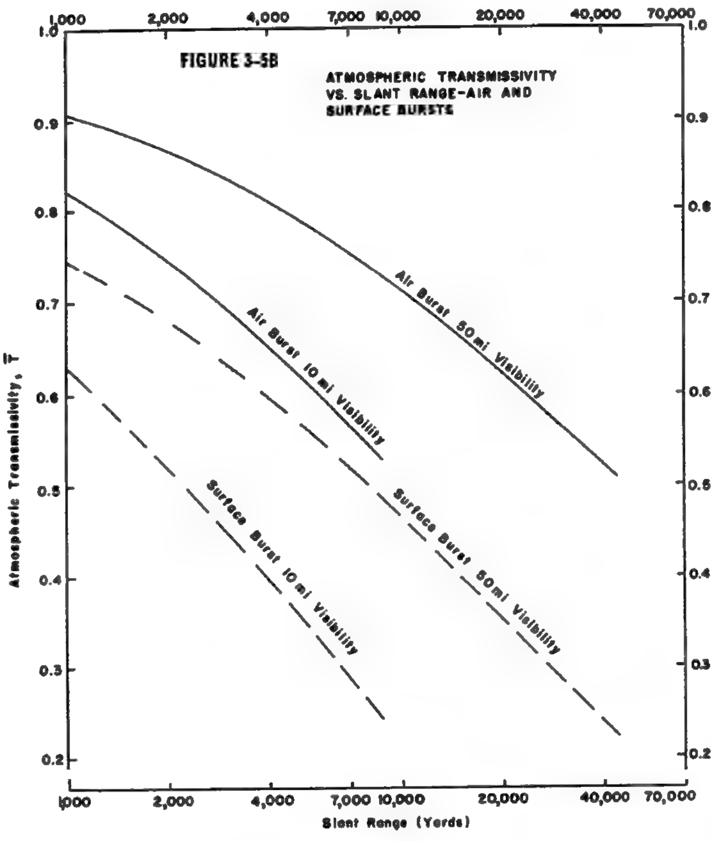


FIGURE 3-5B
ATMOSPHERIC TRANSMISSIVITY VS. SLANT RANGE-AIR AND SURFACE BURSTS

Table 12–2. Critical Radiant Exposure Values for Various Materials

Material	Damage	Critical radiant exposure Q_c, (cal/sq cm)		
		1 KT	100 KT	10 MT
Tent material:				
Canvas, white, 12 oz/yd², untreated	Destroyed	12	21	37
Canvas, OD, 12 oz/yd², flame-proofed	Destroyed	5	9	17
Packaging materials:				
Fibreboard, V2S, BT 350 psi, laminated	Flames during exposure	9	16	29
Fibreboard, V3S, BT 275 psi, laminated	Flames during exposure	7	13	23
Fibreboard, V3C, BT 350 psi, corrugated	Flames during exposure	6	11	19
Fibreboard, W5C, BT 200 psi, corrugated	Flames during exposure	5	10	18
Plywood, douglas fir (¼ in.)	Flames during exposure	9	16	20
Airship material, aluminized, N–113A100, 16 oz/yd²	Aluminum surface discolored	20	35	61
	Aluminum surface destroyed	24	43	75
	Fabric destroyed	27	47	82
Airship material, aluminized, N–113A70, 19.4 oz/yd²	Aluminum surface discolored	10	18	31
	Aluminum surface destroyed	15	27	44
	Fabric destroyed	20	35	61
Airship material, aluminized, N–128A170, 8 oz/yd²	Delaminates	2	4	7
	Fabric destroyed	5	10	17
Doped fabrics (used on some aircraft control surfaces):				
Cellulose nitrate covered with 0.0015″ thick aluminum foil.	Sporadic flaming	60	80	140
Cellulose nitrate, aluminized	Persistent flaming	5	6	10
Plastics:				
Laminated methyl methacrylate	Surface melts	73	120	230
USAF window plastic (½ in.)	Bubbling	240	430	750
Vinylite (opaque), ⅛ in. thick	Dense smoking	3	4	6
	Flaming	20	20	25
Sand:				
Coral	Explosion*	15	27	47
Siliceous	Explosion*	11	19	35
Sandbags: Cotton canvas, dry, filled	Failure	10	18	32
Wood, white pine	0.1 mm depth char	10	18	32
White pine, given protective coating	0.1 mm depth char	40	71	126
Construction materials:				
Roll roofing, mineral surface	Surface melts	8	14	25
	Flaming during exposure	22	40	71
Roll roofing, smooth surface	Surface melts	4	7	12
	Flaming during exposure	9	16	29

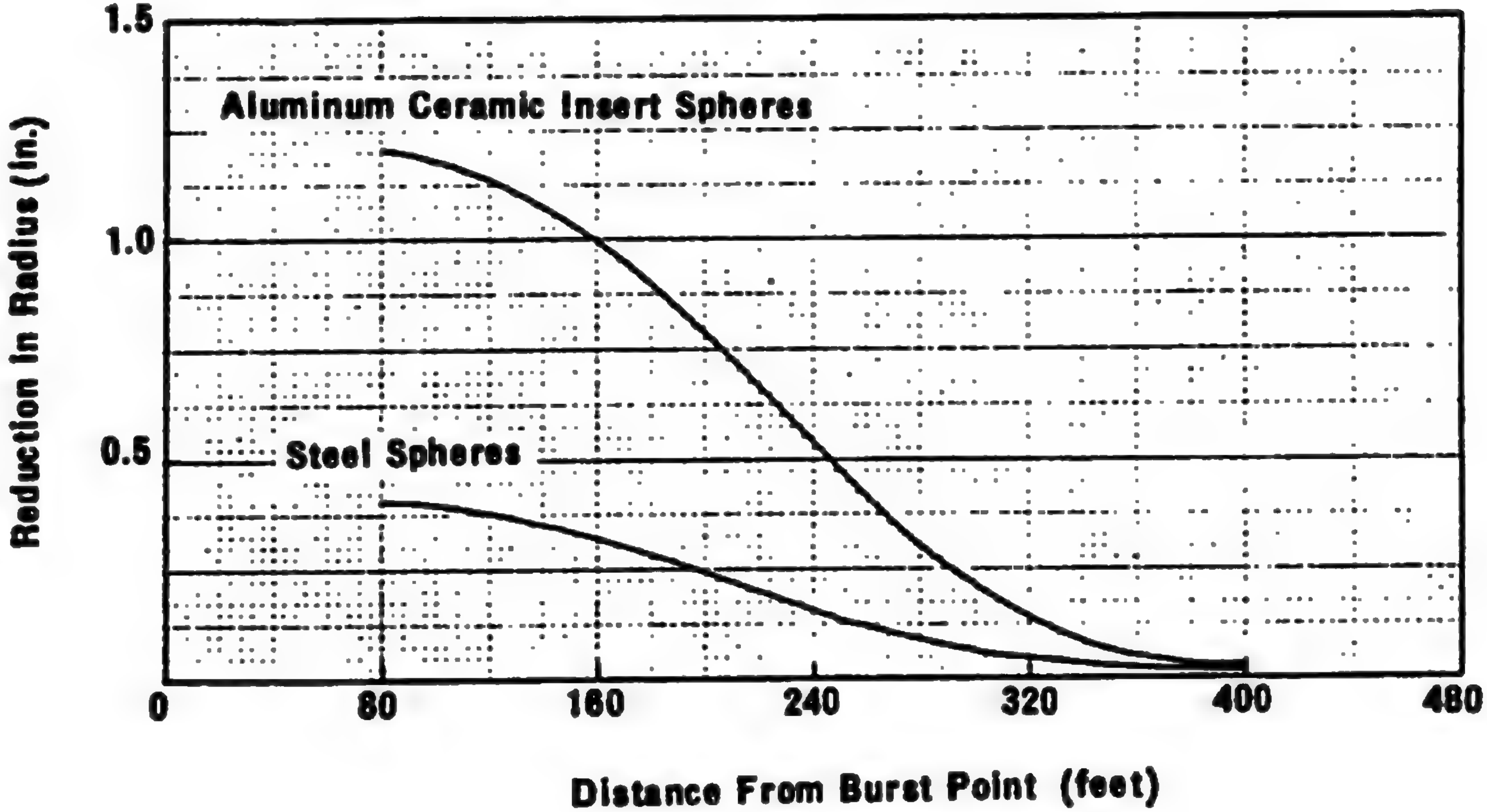
*"Popcorning."

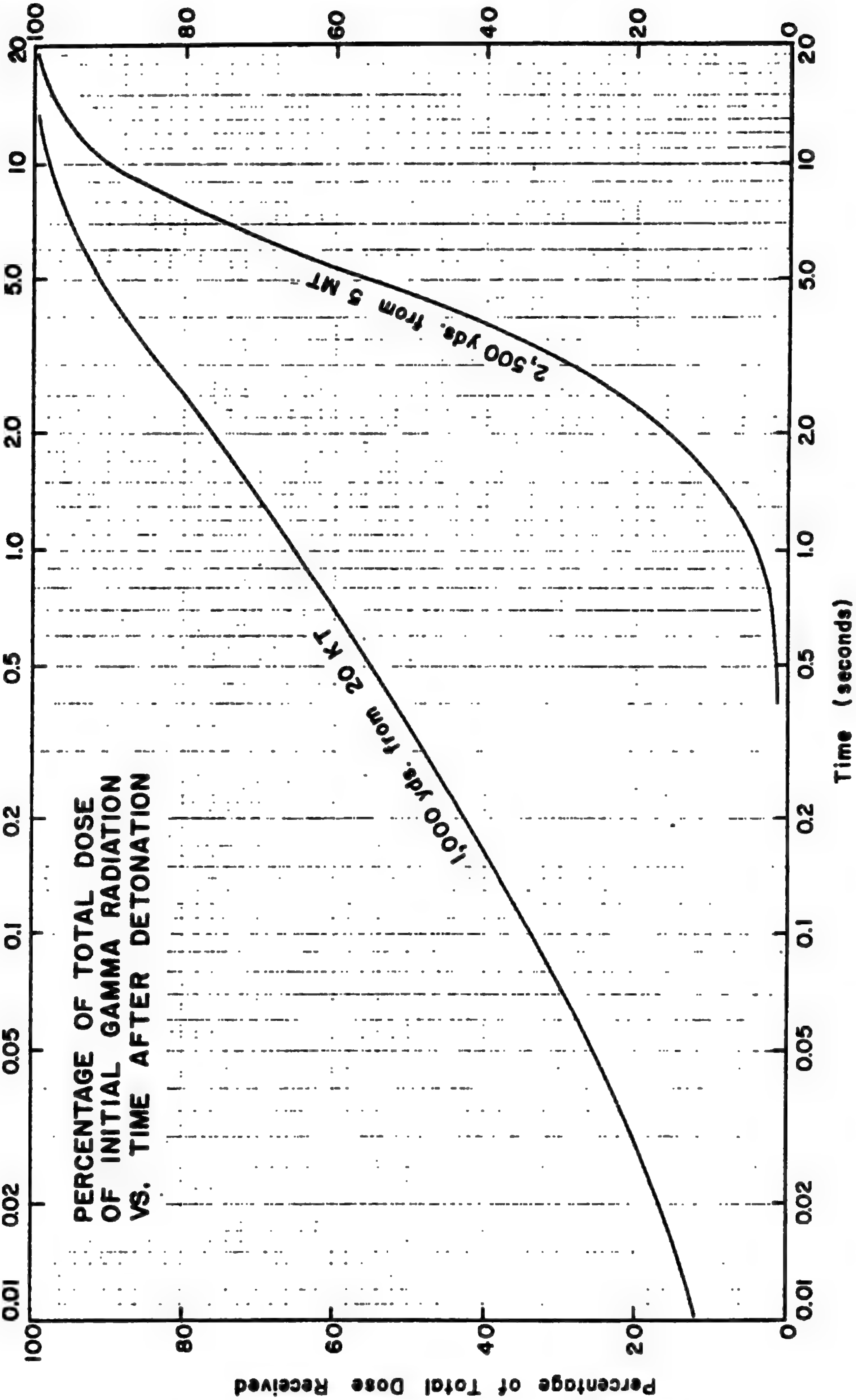
FIGURE 12-5B

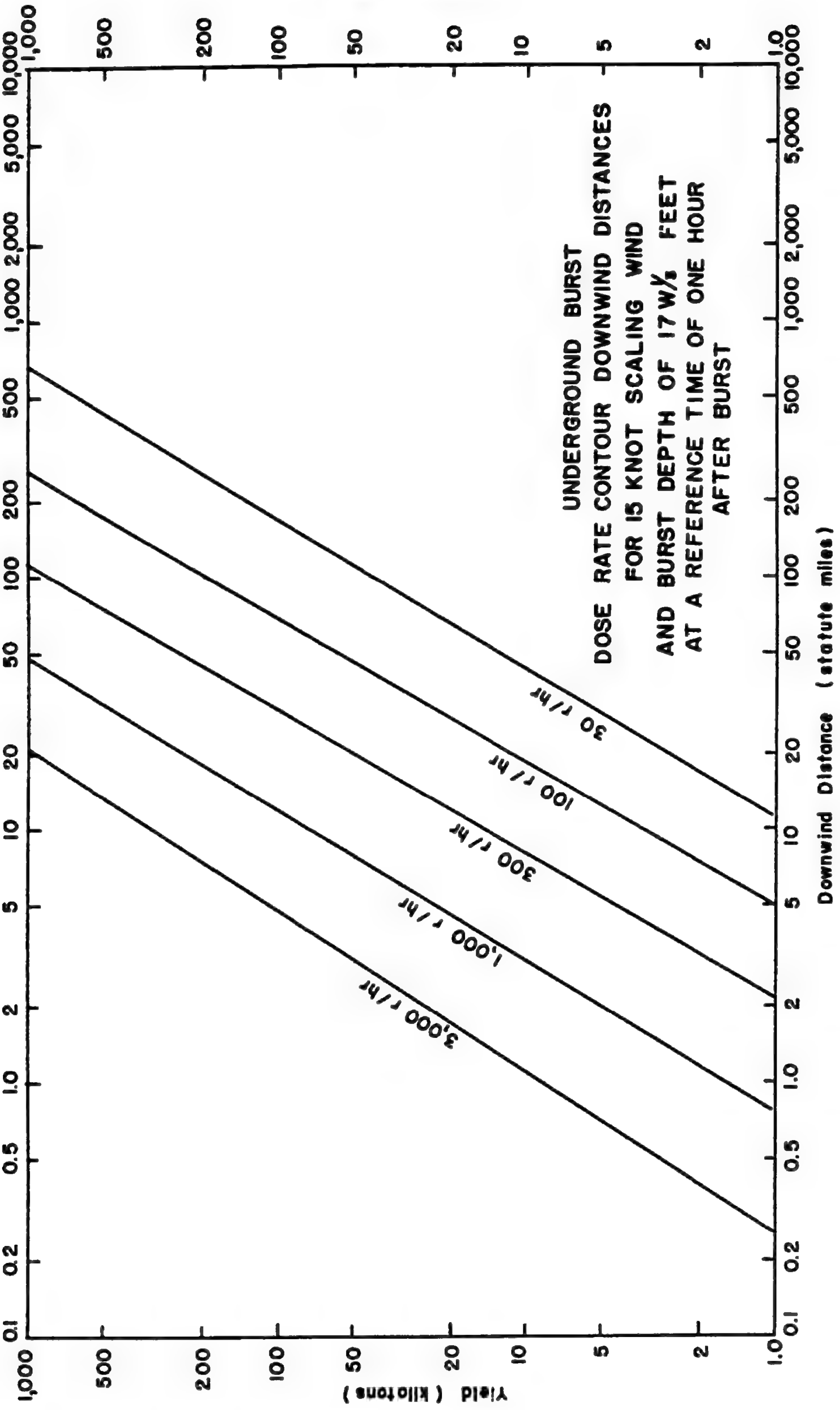
TEAPOT-MET 1955 ablation of spheres inside fireball

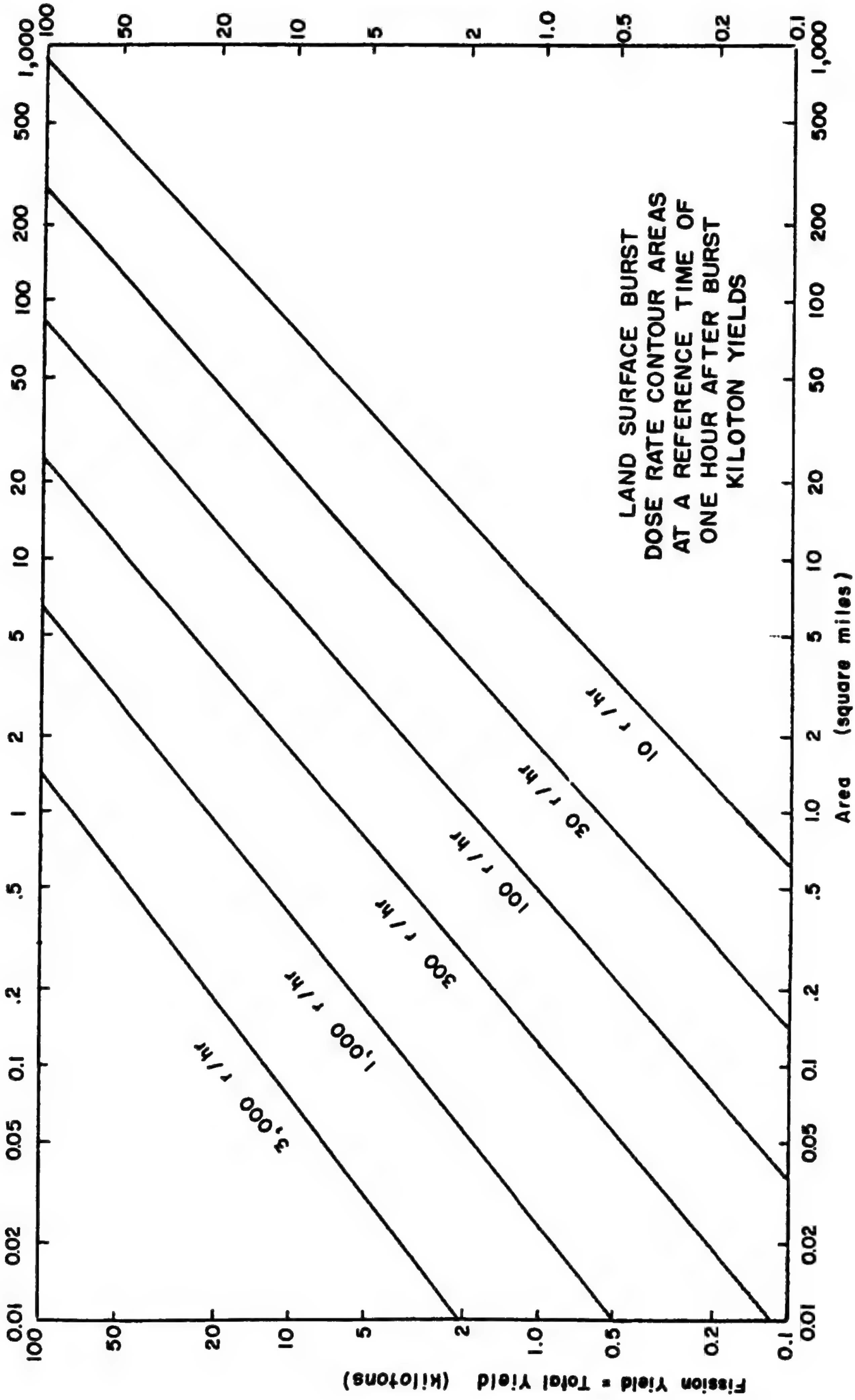
10 inch diameter spheres

REDUCTION OF SPHERE RADIUS WITH DISTANCE FROM A 23 KT BURST
FOR ALUMINUM, STEEL, CERAMIC INSERT SPHERES




PERCENTAGE OF TOTAL DOSE
OF INITIAL GAMMA RADIATION
VS. TIME AFTER DETONATION
1,000 yds. from 20 KT
2,500 yds. from 5 MT
Time (seconds)
Percentage of Total Dose Received
0.01
0.02
0.05
0.1
0.2
0.5
1.0
2.0
5.0
10
20
0
20
40
60
80
100


UNDERGROUND BURST
DOSE RATE CONTOUR DOWNWIND DISTANCES
FOR 15 KNOT SCALING WIND
AND BURST DEPTH OF 17 W^1/3 FEET
AT A REFERENCE TIME OF ONE HOUR
AFTER BURST
30 r/hr
100 r/hr
300 r/hr
1,000 r/hr
3,000 r/hr
Yield (kilotons)
Downwind Distance (statute miles)
1,000
500
200
100
50
20
10
5
2
1.0
0.1
0.2
0.5
1.0
2
5
10
20
50
100
200
500
1,000
2,000
5,000
10,000


LAND SURFACE BURST
DOSE RATE CONTOUR AREAS
AT A REFERENCE TIME OF
ONE HOUR AFTER BURST
KILOTON YIELDS
10 r / hr
30 r / hr
100 r / hr
300 r / hr
1,000 r / hr
3,000 r / hr
Area (square miles)
Fission Yield = Total Yield (kilotons)
0.01
0.02
0.05
0.1
.2
.5
1
2
5
10
20
50
100
200
500
1,000
100
50
20
10
5
2
1.0
0.5
0.2
0.1

DNA EM-1
PART I

DEFENSE NUCLEAR AGENCY EFFECTS MANUAL NUMBER 1

CAPABILITIES OF NUCLEAR WEAPONS

1 JULY 1972

HEADQUARTERS
Defense Nuclear Agency
Washington, D.C. 20305

DNA EM-1
PART I
CHANGE 2
1 AUGUST 1981

DEFENSE NUCLEAR AGENCY EFFECTS MANUAL NUMBER 1

CAPABILITIES OF NUCLEAR WEAPONS

PART I
PHENOMENOLOGY

HEADQUARTERS
Defense Nuclear Agency
Washington, D.C. 20305

EDITOR
PHILIP J. DOLAN
SRI INTERNATIONAL

FOREWORD

This edition of the *Capabilities of Nuclear Weapons* represents the continuing efforts by the Defense Nuclear Agency to correlate and make available nuclear weapons effects information obtained from nuclear weapons testing, small-scale experiments, laboratory effort and theoretical analysis. This document presents the phenomena and effects of a nuclear detonation and relates weapons effects manifestations in terms of damage to targets of military interest. It provides the source material and references needed for the preparation of operational and employment manuals by the Military Services.

The *Capabilities of Nuclear Weapons* is not intended to be used as an employment or design manual by itself, since more complete descriptions of phenomenological details should be obtained from the noted references. Every effort has been made to include the most current reliable data available on 31 December 1971 in order to assist the Armed Forces in meeting their particular requirements for operational and target analysis purposes.

Comments concerning this manual are invited and should be addressed:

Director
Defense Nuclear Agency
ATTN: STAP
Washington, D. C. 20305

C. H. DUNN
Lt General, USA
Director

[redacted]

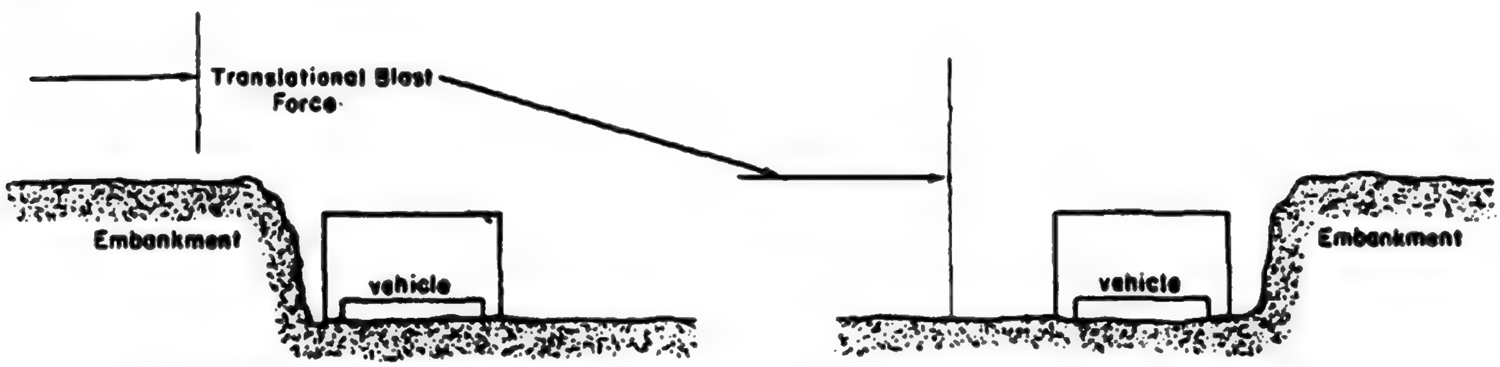
Shielding is most effective when the obstacle is between the target and ground zero.

[redacted] Obstacles that are considered in the assessment of the effects of shielding from air blast are local obstacles, such as ravines, constructed slots, or revetments (the effects of large terrain features on blast waves are discussed in paragraphs 2-38 through 2-41 of Chapter 2). The importance of shielding is well documented. Comparisons of damage between shielded and unshielded vehicles exposed to blast from both nuclear and chemical explosions are available. The effectiveness of an obstacle in shielding a target generally results as much from its capability to reduce the target movement as from its ability to modify the blast environment. Figure 14-8 illustrates this point. When the obstacle is between the blast wave and the target most of the impulse or translational force that induces motion (drag loading) does not act on the target. When the obstacle is "behind" the target, the translational force initially applied to the target is the same as it would have been without an obstacle, but the obstacle not only can modify later translational forces (as a result of shock wave reflection), but it can restrict movement, the major cause of damage. The overpressure effects of crushing and fracturing still occur in both cases, and these effects provide lower limits for damage ground distances.

[redacted] Most damage resulting from low yield weapons is caused by overpressure impulse rather than translation, even for unshielded targets, and, since overpressure impulse is not altered drastically by shielding, the effects of shielding are relatively minor for such weapons. However, most damage caused to non-shielded targets by higher yield weapons results from the translational effects of dynamic pressure. Since shielding can reduce translational effects substantially, it can be quite effective as a protection from large yield weapons. Damage to shielded targets results largely from overpressure effects, for which damage distances scale as the cube root of the yield ($W^{1/3}$), while damage to unshielded targets results largely from total impulse effects (including those of dynamic pressure), for which damage distances generally scale as $W^{0.4}$. The effects of shielding are illustrated in Figure 14-9, in which damage distances for shielded targets have been scaled as $W^{1/3}$, and those for unshielded targets by $W^{0.4}$.

14-5 Effects of Ground Surface Conditions [redacted]

[redacted] Ground surface conditions affect damage in two ways: by modification of the blast parameters; and by modification of target response.



(a) No translation because Translational Force is not applied

(b) No or little translation because embankment restricts movement

Figure 14-8. [redacted] The Effect of Shielding [redacted]

Table 10-1 Estimated Casualty Production in Buildings for Three Degrees of Structural Damage

Structural Damage	Percent of Personnel*		
	Killed Outright	Serious Injury (hospitalization)	Light Injury (no hospitalization)
1-2 story brick homes (high-explosive data from England):			
Severe damage	25	20	10
Moderate damage	<5	10	5
Light damage	–	<5	<5
Reinforced-concrete buildings (nuclear data from Japan):			
Severe damage	100	–	–
Moderate damage	10	15	20
Light damage	<5	<5	15

*These percentages do not include the casualties that may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentages of casualties expected at the maximum range where a specified structural damage occurs. See Chapter 11 for the distances at which these degrees of damage occur for various yields.

A parameter that is useful for calculating thermal response of materials is the characteristic thermal response time τ_o, given by the equation

$$\tau_o = \rho C_p L^2/k \text{ sec},$$

where k is thermal conductivity (cal-sec^{-1} cm^{-1}°C^{-1}), ρC_p is heat capacity per unit volume (ρ = density in g-cm^{-3} and C_p = specific heat at constant pressure in cal-g^{-1}°C^{-1}), and L is the thickness, in centimeters, of the layer of material.

The quantity

$$\alpha = \frac{k}{\rho C_p}$$

is called thermal diffusivity (cm^2/sec). Use of this quantity simplies the previous equation to

$$\tau_o = \frac{L^2}{\alpha} \text{ sec.*}$$

For any particular material exposed to a rectangular pulse of length τ, the previous equation can be transformed to give a characteristic thickness

$$\delta = \sqrt{\alpha\tau} \text{ cm.}$$

for which the characteristic time is equal to the pulse duration. If a thick slab of this material is exposed to a pulse of length τ, the temperature rise at the surface is the same as would be produced by uniformly distributing the absorbed thermal energy in a slab of thickness δ, and the peak temperature rise at depth δ in the thick slab is about half as great as the peak temperature rise at the surface.

For example, consider a block of red pine that is exposed to 15 cal/cm^2 from a rectangular pulse of 3 seconds duration. From Table 9-1,

$$\delta = \sqrt{\alpha\tau} = \sqrt{(24 \times 10^{-3})(3)} = 0.085 \text{ cm.}$$

*This equation is useful, but it is by no means exact. The simplified heat-flow analysis from which this equation is derived neglects the effects of radiation and convection heat losses from the surfaces of the exposed sample. It also assumes an isotropic medium, i.e., a medium whose structure and properties in the neighborhood of any point are the same relative to all directions through the point. It also neglects the changes in thermal properties that occur as the exposed material heats, volatilizes, chars, and bursts into flame.

The heat absorbed by the wood before it begins to scorch is equal to the product of the incident radiant energy, Q, and the absorption coefficient, A.

$$\Delta T_s = \frac{QA}{\rho\delta C_p} = \frac{QA}{\rho C_p \sqrt{\alpha\tau}} = \frac{QA}{\rho C_p \sqrt{\tau k/\rho C_p}}.$$

where ΔT_s is the peak temperature rise at the surface. The parameters that define the thermal pulse may be separated from those that define the material properties, and

$$\Delta T_s = \left(\frac{Q}{\sqrt{\tau}}\right)\left(\frac{A}{\sqrt{k\rho C_p}}\right).$$

For a fixed rectangular pulse, $Q/\sqrt{\tau}$ is a constant, and the equation may be written

$$\Delta T_s = (K)\left(\frac{A}{\sqrt{k\rho C_p}}\right).$$

Sustained ignition only occurs when higher radiant exposures raise the temperature throughout the thickness of the cellulose to a level that is sufficiently high to sustain the flow of combustible gases from breakdown of the fuel. It is difficult to supply sufficient energy with short pulses, since a large amount of the energy that is deposited is carried away by the rapid ablation of the thin surface layer. This transient flaming phenomenon is typical of the response of sound wooden boards to a thermal pulse.

Table 9-1. [redacted] Thermal Properties of Materials [redacted]

Materials	Density, ρ (gm/cm^3)	Specific Heat, C_p ($cal/gm \cdot {}^\circ C$)	Conductivity, k ($cal/sec \cdot cm \cdot {}^\circ C$)	Diffusivity, α (cm^2/sec)
Insulating Materials				
Air	9.46×10^{-4}	0.24	0.55×10^{-4}	0.22
Asbestos	0.58	0.20	4.6×10^{-4}	$40. \times 10^{-4}$
Balsa	0.12	0.4	1.2×10^{-4}	$25. \times 10^{-4}$
Brick (common red)	1.8	0.2	$16. \times 10^{-4}$	$18. \times 10^{-4}$
Celluloid	1.4	0.35	5.0×10^{-4}	$10. \times 10^{-4}$
Cotton, sateen, green	0.70	0.35	1.5×10^{-4}	2.5×10^{-4}
Fir, Douglas-				
spring growth	0.29	0.4	$2. \times 10^{-4}$	$17. \times 10^{-4}$
summer growth	1.00	0.4	$5. \times 10^{-4}$	$12. \times 10^{-4}$
Fir, white	0.45	0.4	2.6×10^{-4}	$14. \times 10^{-4}$
Glass, window	2.2	0.2	$19. \times 10^{-4}$	$43. \times 10^{-4}$
Granite	2.5	0.19	$66. \times 10^{-4}$	$140. \times 10^{-4}$
Leather sole	1.0	0.36	3.8×10^{-4}	$11. \times 10^{-4}$
Mahogany	0.53	0.36	3.1×10^{-4}	$16. \times 10^{-4}$
Maple	0.72	0.4	4.5×10^{-4}	$16. \times 10^{-4}$
Oak	0.82	0.4	5.0×10^{-4}	$15. \times 10^{-4}$
Pine, white	0.54	0.33	3.6×10^{-4}	$18. \times 10^{-4}$
Pine, red	0.51	0.4	$5. \times 10^{-4}$	$24. \times 10^{-4}$
Rubber, hard	1.2	0.5	3.6×10^{-4}	$60. \times 10^{-4}$
Teak	0.64	0.4	4.1×10^{-4}	$16. \times 10^{-4}$
Metals (100°C)				
Aluminum	2.7	0.22	0.49	1.0
Cadmium	8.65	0.057	0.20	0.45
Copper	8.92	0.094	0.92	1.1
Gold	19.3	0.031	0.75	1.2
Lead	11.34	0.031	0.081	0.23
Magnesium	1.74	0.25	0.38	0.87
Platinum	21.45	0.027	0.17	0.29
Silver	10.5	0.056	0.96	1.6
Steel, mild	7.8	0.11	0.107	1.2
Tin	6.55	0.056	0.14	0.38
Miscellaneous Materials				
Ice (0°C)	0.92	0.492	$54. \times 10^{-4}$	$120. \times 10^{-4}$
Water	1.00	1.00	$14. \times 10^{-4}$	$14. \times 10^{-4}$
Skin (porcine, dermis, dead)	1.06	0.77	$9. \times 10^{-4}$	$11. \times 10^{-4}$
Skin (human, living, averaged for upper 0.1 cm)	1.06	0.75	$8. \times 10^{-4}$	$30. \times 10^{-4}$
Polyethylene (black)	0.92	0.55	$8. \times 10^{-4}$	$17. \times 10^{-4}$

If the pulse is of long duration, the ignition threshold rises because the exposed material can dissipate an appreciable fraction of the energy while it is being received. For very long rectangular pulses an irradiance of about 0.5 cal · $cm^{-2} sec^{-1}$ is required to ignite the cellulose. Heat supplied to the material at a slow rate is just sufficient to offset radiative and convective heat losses, while maintaining the cellulose at the ignition temperature of about 300°C.

9-19

Most thick, dense materials that ordinarily are considered inflammable do not ignite to persistent flaming ignition when exposed to transient thermal radiation pulses. Wood, in the form of siding or beams, may flame during the exposure but the flame is extinguished when the exposure ceases.

9-25

Table 9-2. [redacted] Approximate Radiant Exposures for Ignition of Fabrics [redacted]

Material	Weight (oz/yd^2)	Color	Effect on Material	Radiant Exposure* (cal/cm^2) t_{max} 0.2 sec	t_{max} 1.0 sec	t_{max} 3.2 sec
Clothing Fabrics						
Cotton	8	White	Ignites	32	48	85
		Khaki	Tears on flexing	17	27	34
		Khaki	Ignites	20	30	39
		Olive	Tears on flexing	9	14	21
		Olive	Ignites	14	19	21
		Dark blue	Tears on flexing	11	14	17
		Dark blue	Ignites	14	19	21
Cotton corduroy	8	Brown	Ignites	11	16	22
Cotton denim, new	10	Blue	Ignites	12	27	44
Cotton shirting	3	Khaki	Ignites	14	21	28
Cotton-nylon mixture	5	Olive	Tears on flexing	8	15	17
	5	Olive	Ignites	12	28	53
Wool	8	White	Tears on flexing	14	25	38
		Khaki	Tears on flexing	14	24	34
		Olive	Tears on flexing	9	13	19
		Dark blue	Tears on flexing	8	12	18
	20	Dark blue	Tears on flexing	14	20	26
Rainwear (double-neoprene-coated nylon twill)	9	Olive	Begins to melt	5	9	13
	9	Olive	Tears on flexing	8	14	22
Drapery Fabrics						
Rayon gabardine	6	Black	Ignites	9	20	26
Rayon-acetate drapery	5	Wine	Ignites	9	22	28
Rayon gabardine	7	Gold	Ignites	**	24†	28†
Rayon twill lining	3	Black	Ignites	7	17	25
Rayon twill lining	3	Biege	Ignites	13	20	28
Acetate-shantung	3	Black	Ignites	10†	22†	35†
Cotton heavy draperies	13	Dark colors	Ignites	15	18	34
Tent Fabrics						
Canvas (cotton)	12	White	Ignites	13	28	51
Canvas	12	Olive drab	Ignites	12	18	28
Other Fabrics						
Cotton chenille bedspread		Light blue	Ignites	**	11†	15†
Cotton venetian blind tape, dirty		White	Ignites	10	18	22
Cotton venetian blind tape		White	Ignites	13†	27†	31†
Cotton muslin window shade	8	Green	Ignites	7	13	19

[redacted] Radiant exposures for the indicated responses (except where marked †) are estimated to be valid to ±25% under [redacted]ndard laboratory conditions. Under typical field conditions the values are estimated to be valid within ±50% with a greater likelihood of higher rather than lower values. For materials marked †, ignition levels are estimated to be valid within ±50% under laboratory conditions and within ±100% under field conditions. For low air bursts, values of t_{max} of 0.2, 1.0, and 3.2 sec correspond roughly to yields of 40 kt, 2 Mt, and 24 Mt, respectively.

** [redacted] Data are not available or appropriate scaling not known.

3-2 Range Effects

As the thermal energy propagates away from the fireball, the divergence that results from the increasing area through which it passes causes the radiant exposure to decrease as the inverse square of the slant range. At a slant range R centimeters from the source, the thermal energy is distributed over a spherical area of $4\pi R^2$. Since the thermal yield in calories is 10^{12} Wf, where W is the yield in kilotons, the radiant exposure at a distance R cm in a clear atmosphere is

$$Q = \frac{10^{12} Wf}{4\pi R^2} \text{ cal/cm}^2.$$

Adding the transmittance factor to the equations given in paragraph 3-2 gives

$$Q = \frac{7.96\ WfT}{R_{km}^2} \text{ cal/cm}^2,$$

$$R_{km} = 2.82\ \sqrt{WfT/Q.}$$

3-5

The scattering and absorption properties of the atmosphere depend partly on the wavelength of the radiant energy. Wavelength is often measured in microns (1 micron = 10^{-6} meter), for which the symbol is μ. Wavelengths in the visible spectrum may be identified by the relation between wavelength and color: light with a wavelength of 0.7 μ is red; 0.58 μ light is yellow; and 0.48 μ light is blue. White light is a mixture containing all wavelengths in the visible spectrum, which extends from 0.38 to 0.78 μ. The infrared spectrum consists of radiant energy at wavelengths longer than 0.78 μ, and the ultraviolet spectrum consists of radiant energy at wavelengths shorter than 0.38 μ.

The energy transport properties of atmospheric particles may be expressed in terms of scattering and absorption cross sections, which are fictitious areas that are a measure of the probability that scattering or absorption will occur. Particles that are small compared to the wavelength of light have scattering cross sections that are inversely proportional to the fourth power of the wavelength. Therefore, air molecules scatter light from the extreme blue end of the visible spectrum (wavelength = 0.38 μ) about 16 times as effectively as they scatter light from the red end of the spectrum (wavelength = 0.78 μ).

The sky is blue because most of the scattering at high altitudes is by air molecules, which scatter blue light more efficiently than they scatter other colors of the visible spectrum. A distant mountain appears blue on a clear day for the same reason.

3-7

The principal absorber of thermal energy usually is water vapor, which has strong absorption bands in the infrared spectrum. Dry air transmits infrared energy more efficiently than humid air. Carbon dioxide and other gases present in the atmosphere in small amounts also absorb infrared energy.

Ultraviolet energy is absorbed most strongly at the shorter wavelengths: the limiting wavelength that air in the lower atmosphere will transmit is about 0.2 micron. Ozone, appreciable quantities of which are found between roughly 60,000 and 80,000 feet, absorbs ultraviolet radiation with wavelengths shorter than 0.29 micron. As a result of these absorption bands ultraviolet energy that reaches the earth from the sun is almost entirely limited to the spectral band between 0.38 micron (the violet edge of the visible spectrum) and 0.29 micron.

3-8

The attenuation for light of 0.65 micron wavelength was used to specify $\tau(h)$. This choice was a purely empirical one, used because it brought the calculated values of transmittance into general agreement with experimentally determined values. The wavelength that was selected is attenuated less than is the thermal radiation spectrum as a whole;

For bursts below one-quarter mile and surface targets, a wavelength of 0.55 microns was used together with a buildup factor, as described below.

$$T_d = e^{-2.9 \;R/V},$$

where T_d is the transmission coefficient for *direct* flux over a path of slant range R, and V is visual range. As mentioned above, scattered as well as direct flux must be considered. Consequently, transmittance is larger than the transmission coefficient for direct flux and is given approximately by the following empirical equation:

$$T = e^{-2.9 \;R/V} \;(1 + 1.9\; R/V).$$

The exponential factor in this equation accounts for energy loss from the direct beam by scattering. The expression in brackets is a buildup factor that accounts for energy scattered toward the target.

When the burst height h is greater than about one-quarter mile, transmittance may be calculated from

$$T = e^{-\tau(h)\;\frac{16}{V}\;\frac{R}{h}}$$

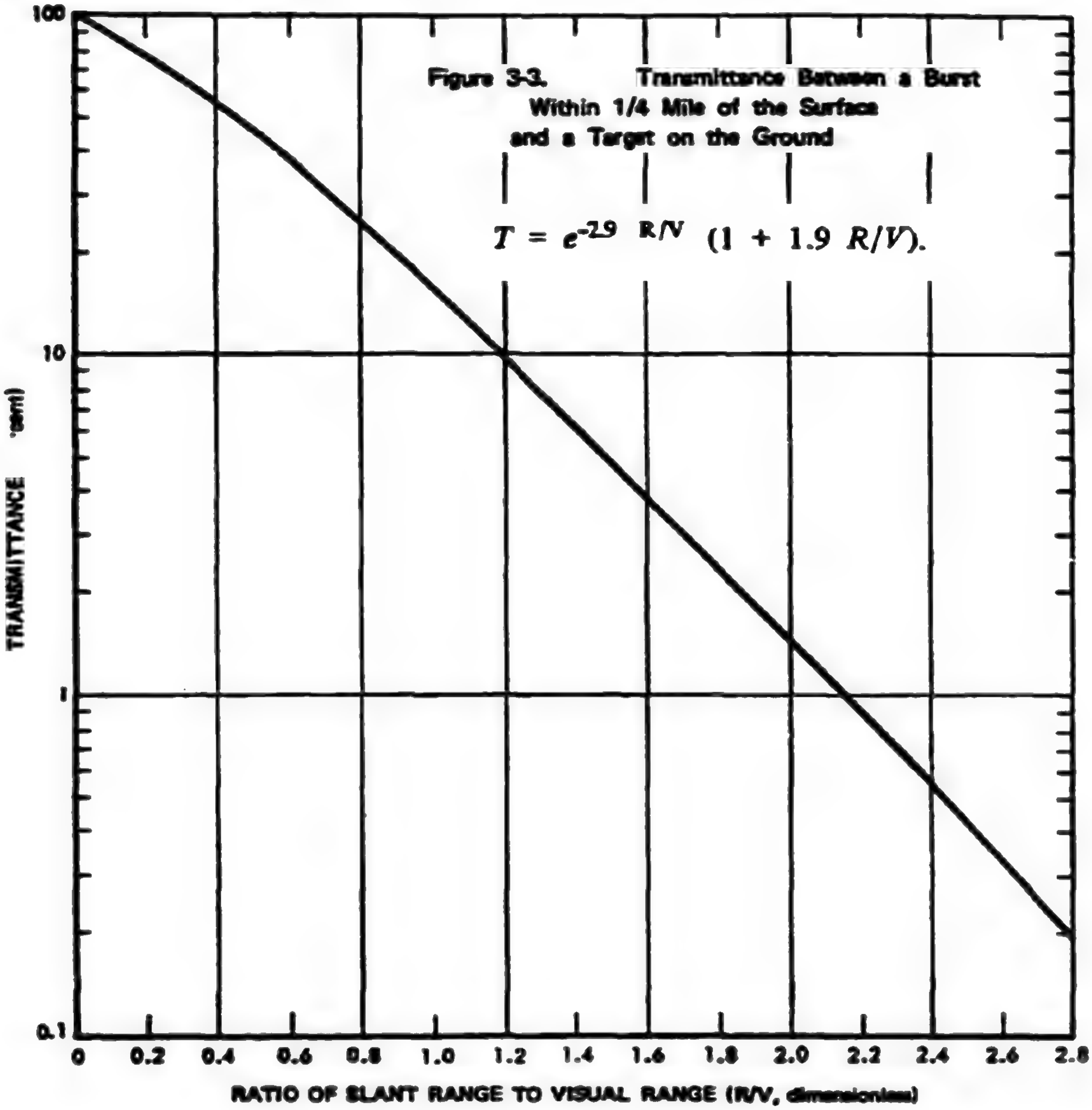


Figure 3-3. Transmittance Between a Burst Within 1/4 Mile of the Surface and a Target on the Ground

Thermal flash on forest leaf canopy produces smoke-screen (in Nevada and Pacific nuclear tests), shadowing dry leaf litter

The high degree of shading by tree crowns and stems for detonations at or below the canopy level often may be offset by scattering of burning debris ignited within the fireball. 15-59

Fuels seldom burn vigorously, regardless of wind conditions, when fuel moisture content exceeds about 16 percent. This corresponds to an equilibrium moisture content for a condition of 80 percent relative humidity. 15-60

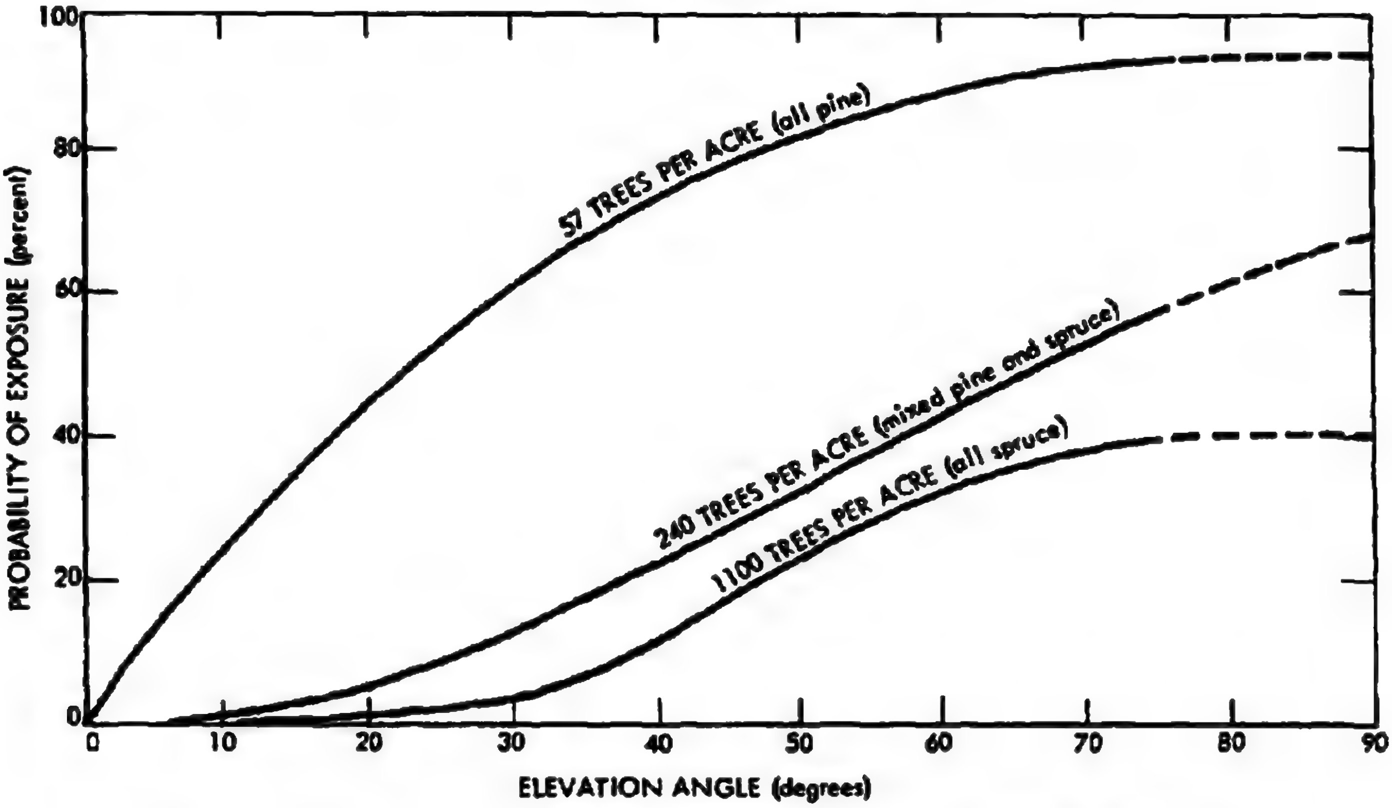


Figure 15-41. Probability of Exposure of Forest Floor for Different Levels of Tree Density

Table 15-13 Burning Durations by Fuel Type

Fuel Type	Violent Burning: Time (min)	Violent Burning: Energy Release (percent)	Residual Burning: Time (min)	Residual Burning: Energy Release (percent)	Total Burning Time
Grass	1.5	90	0.5	10	30 min
Light Brush (12 tons/acre)	2.	60	6.	40	16 hr
Medium Brush (25 tons/acre)	6.	50	24.	50	36 hr
Heavy Brush (40 tons/acre)	10.	40	70.	60	72 hr
Timber	24.	17	157.	83	7 days

Table 15-11 [redacted] Criteria of "No-Spread" of Fires [redacted]

Fuel Type	Criteria
All forest fuels	Over 1 inch of snow on the ground at the nearest weather stations.
Grass	Relative humidity above 80 percent.
Brush or hardwoods	0.1 inch of precipitation or more within the past 7 days and: Wind 0-3 mph; relative humidity 60 percent or higher, or Wind 4-10 mph; relative humidity 75 percent or higher, or Wind 11-25 mph; relative humidity 85 percent or higher.
Conifer timber	1. One day or less since at least 0.25 inch of precipitation and: Wind 0-3 mph; relative humidity 50 percent higher, or Wind 4-10 mph; relative humidity 75 percent higher, or Wind 11-25 mph; relative humidity 85 percent or higher. 2. Two to three days since at least 0.25 inch of precipitation and: Wind 0-3 mph; relative humidity 60 percent or higher, or Wind 4-10 mph; relative humidity 80 percent or higher, or Wind 11-25 mph; relative humidity 90 percent or higher. 3. Four to five days since at least 0.25 inch of precipitation and wind 0-3 mph; relative humidity 80 percent or higher. 4. Six to seven days since at least 0.25 inch of precipitation and wind 0-3 mph; relative humidity 90 percent or higher.

[redacted] shielding from the wind and shading from sunlight by the canopy. The spread or no-spread criteria are summarized in Table 15-11. This table lists the conditions under which fire would not be expected to spread.

[redacted] The criteria of Table 15-11 have been compared to the records of 4,378 wildland fires. Of the fires for which "no spread" would be predicted, 97.8 percent did not spread; only 40 percent of the fires that were predicted to spread actually did spread (at a rate of 0.005 mph or faster). This failure to spread often may be attributable to lack of fuel continuity around the point of origin.

[redacted] The criteria of Table 15-11 are considered to be reliable for American forests and suitably conservative to assure a low level of hazard to friendly forces. On the other hand, the criteria are probably not overly conservative to predict conditions for which enemy forces may be denied forested areas because of fire whenever the local weather history and conditions at the time of

14-10 Fire Damage

Damage to equipment by fire is referred to in some damage reports. Although some 20 occurrences have been noted, they involved only a very small percentage of the equipment exposed. Most fires appeared to be secondary in nature, that is, they were not started by direct thermal radiation ignition. Two equipment items were burned during nuclear tests under exposure conditions in which they could have received virtually no thermal radiation. In addition, a 1/4-ton truck exposed at a 100-ton high explosive test (in which thermal radiation was negligible) also burned.

The damage to a 6-kVA generator exposed on a U.K. test is particularly interesting. In the damage report the notation is made, "Fire may have started from fuel from broken carburetor spilling on hot muffler." U.K. practice at nuclear tests was to expose running equipment, that is, the engines were running at the time of the explosion. The six recorded occurrences of fires on U.K. tests represents a considerably larger percentage (about 10 percent) of all U.K. equipment exposed than does the number of fires recorded on U.S. tests. Since this may be due to the U.K. practice of running engines during a test, the incidence of secondary fires in an operational situation may be higher than the U.S. test data indicate.

Seager, E. R. Drake, R. F. C. Butler, *Operation TOTEM Group 12 Report: Effects on a Landrover (car, 5 CWT, 4x4) and Generating Sets* AWRE Report T 79/54(x), FWE-131, Atomic Weapons Research Establishment, Aldermaston, Berks, England, September 1956

[redacted] SURVIVAL IN FIRE AREAS [redacted]

[redacted] The best documented fire storm in history (but not the one causing the greatest loss of life) occurred in Hamburg, Germany during the night of July 27-28, 1943, as a result of an incendiary raid by Allied forces. Factors that contributed to the fire included the high fuel loading of the area and the large number of buildings ignited within a short period of time.

[redacted] The main raid lasted about 30 minutes. Since the air raid warning and the first high explosive bombs caused most people to seek shelter, few fires were extinguished during the attack. By the time the raid ended, roughly half the buildings in the 5 square-mile fire storm area were burning, many of them intensely. The fire storm developed rapidly and reached its peak in two or three hours.

[redacted] Many people were driven from their shelters and then found that nearly everything was burning. Some people escaped through the streets; others died in the attempt; others returned to their shelters and succumbed to carbon monoxide poisoning.

[redacted] Estimates of the number that were killed range from about 40,000 to 55,000. Most of the deaths resulted from the fire storm. Two equally heavy raids on the same city (one occurred two nights earlier; the other, one night later) did not produce fire storms, and they resulted in death rates that have been estimated to be nearly an order of magnitude lower.

[redacted] More surprising than the number killed is the number of survivors. The population of the fire storm area was roughly 280,000. Estimates have been made that about 45,000 were rescued, 53,000 survived in non-basement shelters, and 140,000 either survived in basement shelters or escaped by their own initiative.

9-25 Causes of Death [redacted]

[redacted] The evidence that can be reconstructed from such catastrophes as the Hamburg fire storm indicates that carbon monoxide and excessive heat are the most frequent causes of death in mass fires. Since the conditions that offer protection from these two hazards generally provide protection from other hazards as well, the following discussion is limited to these two causes of death.

[redacted] *Carbon Monoxide.* Burning consists of a series of physical and chemical reactions. For most common fuels, one of the last of the reactions is the burning of carbon monoxide to form carbon dioxide near the tips of the flames. If the supply of air is limited, as it is likely to be if the fire is in a closed room or at the bottom of a pile of debris from a collapsed building, the carbon monoxide will not burn completely. Fumes from the fire will contain a large amount of this tasteless, odorless, toxic gas.

[redacted] During the Hamburg fire, many basement shelters were exposed to fumes. Imperfectly fitting doors and cracks produced by exploding bombs allowed carbon monoxide to penetrate these shelters. The natural positions of many of the bodies recovered after the raid indicated that death had often come without warning, as is frequently the case for carbon monoxide poisoning.

[redacted] Carbon monoxide kills by forming a more stable compound with hemoglobin than either oxygen or carbon dioxide will form. These latter are the two substances that hemoglobin ordinarily carries through the blood stream. Carbon monoxide that is absorbed by the blood reduces the oxygen carrying capacity of the blood, and the victim dies from oxygen deficiency.

[redacted] As a result of the manner that carbon monoxide acts, it can contribute to the death of a person who leaves a contaminated shelter to attempt escape through the streets of a burning city. A person recovering from a moderate case of carbon monoxide poisoning may feel well while he is resting, but his blood may be unable

[redacted]

to supply the oxygen his body needs when he exerts himself. After the air raid at Hamburg. victims of carbon monoxide poisoning. apparently in good health. collapsed and died from the strain of walking away from a shelter. It is suspected that many of the people who died in the streets of Hamburg were suffering from incipient carbon monoxide poisoning.

[redacted] *Heat.* The body cools itself by perspiration. When the environment is so hot that this method fails. body temperature rises. Shortly thereafter. the rate of perspiration decreases rapidly. and. unless the victim finds immediate relief from the heat, he dies of heat exhaustion. Death from excessive heat may occur in an inadequately insulated shelter: it also may occur in the streets if a safe area cannot be located in a short time.

9-26 Shelters [redacted]

[redacted] The results of the Hamburg fire storm illustrate the value of shelters during an intense mass fire. The public air raid shelters in Hamburg had very heavy walls to resist large bombs. Reinforced concrete three feet thick represented typical walls. Some of these shelters were fitted with gas proof doors to provide protection from poison gas. These two features offered good protection from the heat and toxic gases generated by the fire storm.

[redacted] The public shelters were of three types:

- *Bunkers.* These were large buildings of several shapes and sizes, designed to withstand direct hits by large bombs. The fire storm area included 19 bunkers designed to hold a total of about 15,000 people. Probably twice this number occupied the bunkers during the fire storm, and all of these people survived.
- *Splinterproof Shelters.* These were long single story shelters standing free of other buildings and protected by walls of reinforced concrete at least 2-1/2 feet thick. No deaths resulting from the fire storm were reported among occupants of these shelters. These structures were not gasproof. Distance from burning structures and low height of the shelters probably provided protection from carbon monoxide.
- *Basement Shelters.* The public shelters that were constructed in large basements had ceilings of reinforced concrete 2 to 5 feet thick. Although reports indicate that some of the occupants of these shelters survived and some did not, statistics to indicate the chance of survival in such structures are not available.
- *Private Basement Shelters.* Private basements were constructed solidly, but most of them lacked the insulating value of very thick walls and the protection of gas-tight construction. Emergency exits (usually leading to another shelter in an adjacent building) could be broken if collapse of the building caused the normal exit to be blocked. As a result of the total destruction in the fire storm area, this precaution was of limited value. Many deaths occurred in these shelters as a result of carbon monoxide poisoning, and the condition of the bodies indicated that intolerable heat followed the carbon monoxide frequently. In some cases, the heat preceded the poisonous gas and was the cause of death. Generally, these shelters offered such a small amount of protection that the occupants were forced out within 10 to 30 minutes. Most of these people were able to move through the streets and escape. Others were forced out later when the fire storm was nearer its peak intensity, and few of these escaped. A few people survived in private basement shelters.

2-45 Air Blast from Weapons with Enhanced Radiation Outputs

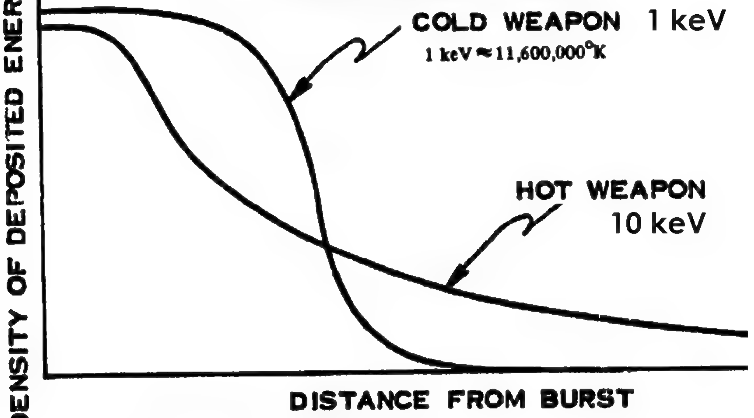


Figure 2-67 Energy Deposition in Air

Rough calculation may be made, however, by applying the following rule of thumb to weapons with enhanced outputs: blast calculations for a given radius may be based on a weapon yield that is equal to the amount of energy contained in the sphere defined by that radius. As this rule implies, the blast wave, as it propagates outward, picks up hydrodynamic energy from the heated air through which it passes. 2-140

THE THERMAL PULSE FROM SPECIAL WEAPONS

As stated in paragraph 2-45, Chapter 2, weapons that have enhanced radiation out- 3-56
puts, i.e., weapons that produce a large fraction of their output in the form of neutrons, gamma rays, or X-rays [redacted] will, in most cases, generate a weaker blast wave than a nominal weapon of the same yield. Similarly, the thermal pulse from such special weapons may be weaker than that from a nominal weapon. The explanation for the reduced thermal output is the same as the explanation for a weaker blast wave: neutrons, gamma rays, and high energy X-rays travel much farther through the atmosphere than the energy from a conventional weapon; therefore, a large portion of the weapon energy may be absorbed by air far from the burst. This air will not become sufficiently hot to contribute effectively to either the blast wave or to the thermal pulse.

[redacted] The terms "nominal weapon" and "conventional weapon" used in the preceding paragraph refer to a nuclear weapon that radiates 70 to 80 percent of its energy as X-rays [redacted] and retains nearly all of the remaining energy as thermal and kinetic energy of the weapon debris (see paragraph 4-4, Chapter 4).

3-17 Effective Thermal Yield of Special Weapons

The modified thermal effects produced by weapons with enhanced outputs may be calculated in terms of an effective thermal yield. This is defined as the yield that a nominal warhead would have in order to radiate the same thermal energy as the special weapon. 3-57

Effective thermal yield is roughly the amount of energy that the nuclear source deposits within a sphere the size of the fireball at the time of the principal minimum. This radius is

$$R_{min} = \frac{29\ W^{0.36}}{(\rho/\rho_o)^{0.22}} \text{ meters,}$$

where W is the weapon yield in kilotons, ρ is the ambient air density at the burst altitude, and ρ_o is the ambient density at sea level.

Energy that is deposited beyond the radius R_{min} is assumed to make a negligible contribution to the energy radiated by the fireball.

Since the size of the fireball is determined by the thermal energy it contains, it would be logical to let W represent effective thermal yield rather than total weapon yield. To do this requires a trial-and-error approach. 3-58

The components of energy deposited within R_{min} of the burst are added together to obtain the effective thermal yield. 3-59

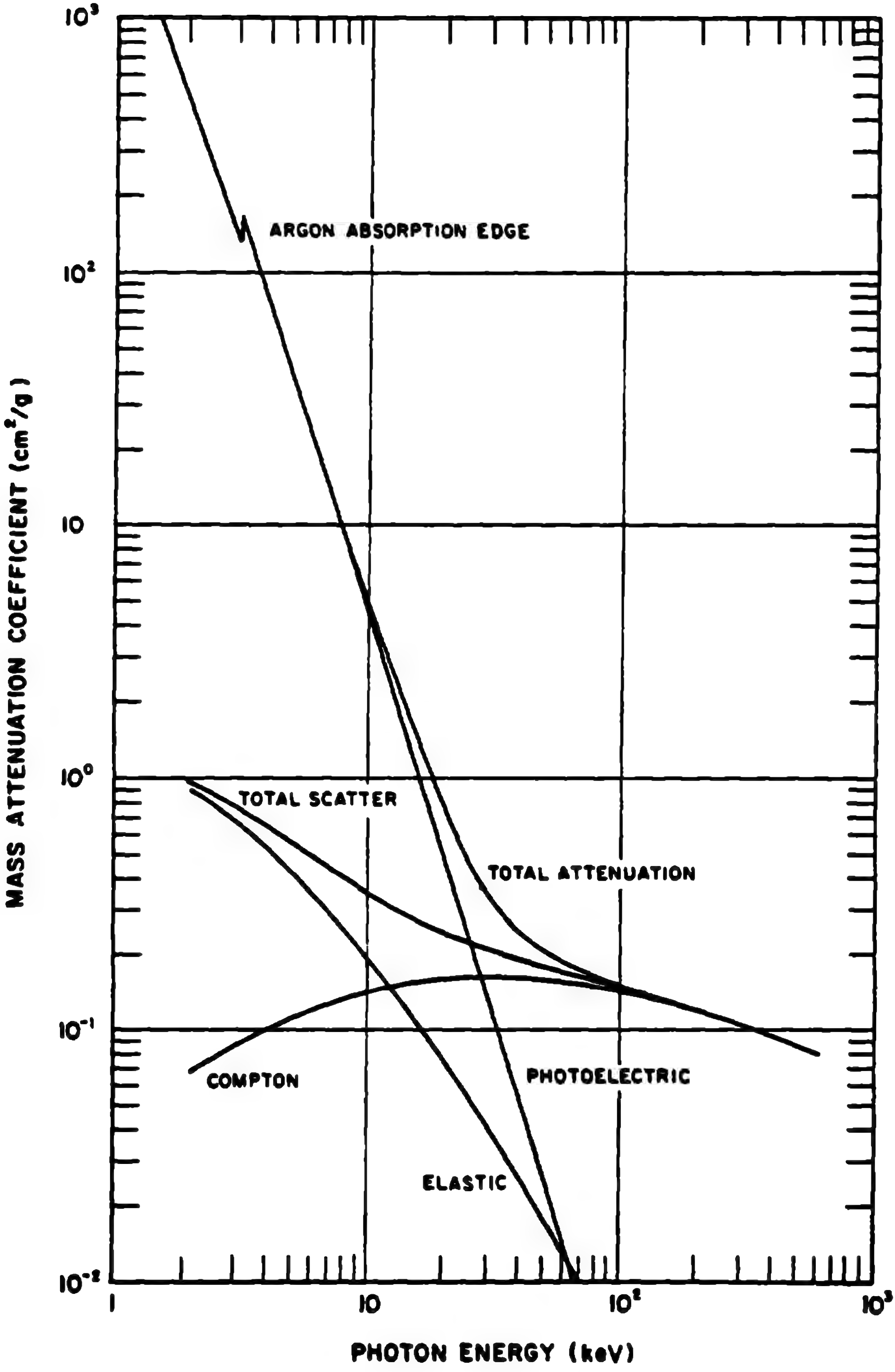


Figure 4-4. Mass Attenuation Coefficients for Air

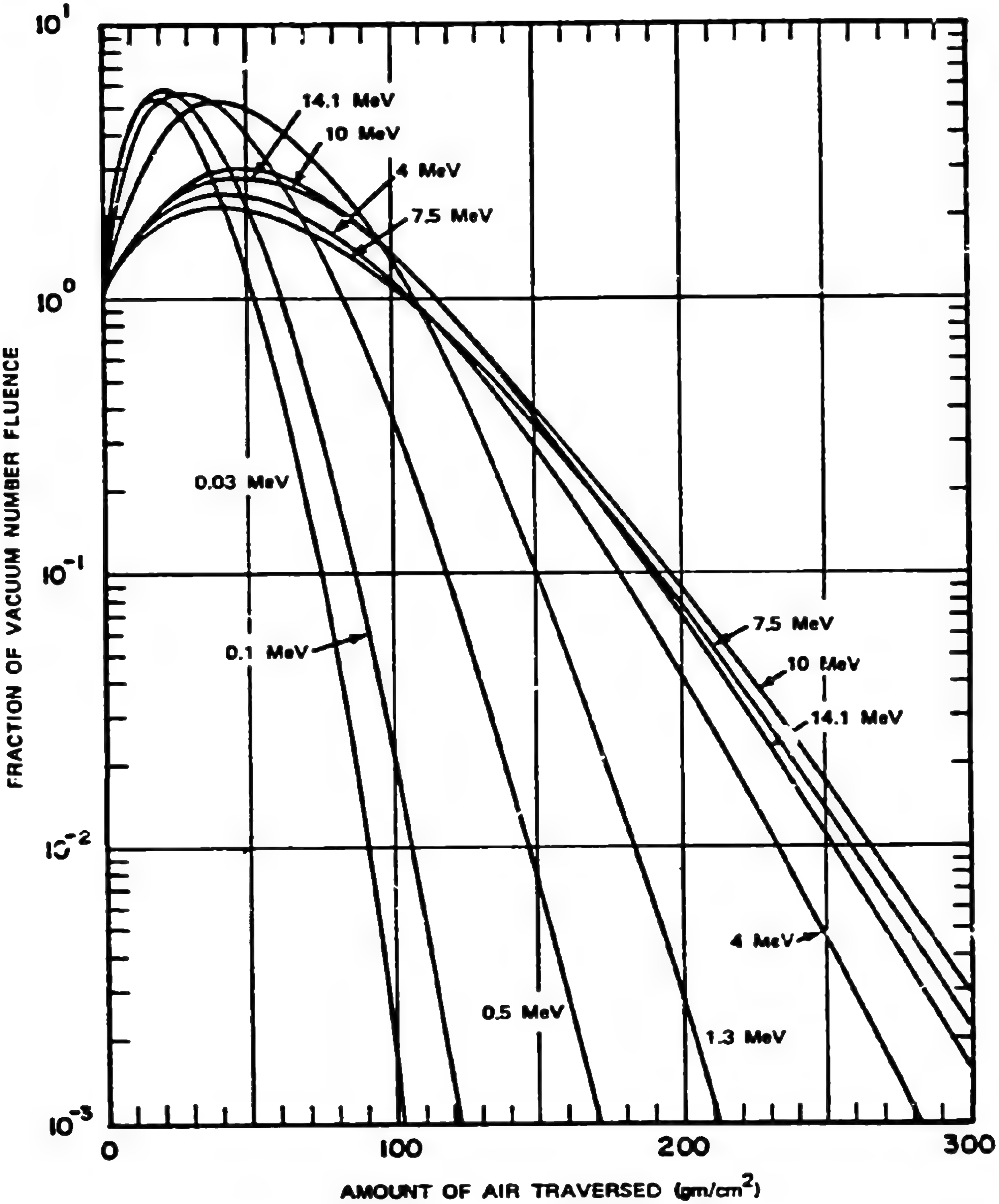


Figure 5-7. Neutron Energy Build-Up Factors for Various Monoenergetic Sources in Homogeneous Air

SECTION V
X-RAY DAMAGE EFFECTS

NTRODUCTION

Nuclear weapons as X-ray sources and the environments they produce are described in Chapter 4.

Cold X-rays (typically 1 to 3 keV black body temperatures) are absorbed in a thin surface layer. At sufficiently high fluence, a short pulse of X-rays can heat the surface rapidly and may cause it to vaporize and blow off. This results in: (1) an impulse imparted to the total structure; and (2) generation of a strong shock wave that propagates into the structure, and which may cause spallation of material at free boundaries and internal fracture of materials and bonds. These latter effects are produced by shock wave propagation through the thickness of a surface structure such as the thermal protection shell of a reentry vehicle. The former effects may produce damage by whole vehicle modes of response to the net impulse.

The hot X-rays are more penetrating. They can cause: (1) thermally generated shock waves in the vehicle structural materials and internal components; (2) melting and vaporization of the substructure: (3) internal deposition of energy in electronic components producing transient or permanent damage (see Chapter 6 and Section 7 of this chapter): or (4) produce internal EMP signals (see Chapter 7).

While some nuclear weapons emit only cold X-rays, all hot X-ray weapons have a cold component. Hence, for exoatmospheric events the hot X-ray effects are accompanied by cold X-ray effects. On the other hand, for endoatmospheric explosions, the cold X-rays have short mean free paths, and the X-ray effects beyond distances of a few tens of meters are produced by hot X-rays alone.

All vulnerability analyses follow similar computational steps:

1. The X-ray energy deposition is computed using known processes for the materials and structure. This energy is assumed most often to be deposited instantaneously.
2. From the calculated energy deposition and the equation of state for the materials in the structure (if known) for the liquid, solid, and vapor phases of the material, a stress wave, which propagates through the surface structure, is calculated.
3. Damage to the surface structure that results from the stress wave (spallation, internal fracturing, delamination and debonding), is determined.
4. The response of the whole structure that results from the impulse imparted to it is determined.

X-RAY ENERGY DEPOSITION CALCULATIONS

The starting point of all X-ray vulnerability analysis is a calculation of the X-ray energy deposition.

9-33 X-ray Cross Sections

The probability of a photon of energy $h\nu$ traversing a distance of absorbing material x is $e^{-\mu x}$, where μ is the linear attenuation coefficient. This probability also can be written as $e^{-(\mu/\rho)\rho x}$, where μ/ρ is the mass attenuation coefficient for the material (see paragraph 4-3). In this representation, μ/ρ is in cm^2/gm and ρx is the thickness in gm/cm^2, i.e., the mass of material in the column of 1 square centimeter cross section and x centimeters long.

If the monoenergic X-ray fluence incident normal (perpendicular) to the material sur-

face is φ_0. the direct fluence after traversing a thickness of absorbing material is

$$\varphi_{dir} = \varphi_0 e^{-(\mu/\rho)\rho x} \text{ cal/cm}^2.$$

Mass attenuation coefficients for the elements beryllium, aluminum, iron, copper, tungsten, and uranium are given in Tables 9-10 through 9-15, and Figures 9-27 through 9-32, respectively. These are representative of metallic materials used in aerospace systems. Mass attenuation coefficients for ablator materials, carbon phenolic and tape-wound silicon phenolic are shown in Figures 9-33 and 9-34, respectively. In these tables and figures, Z is the atomic number, μ_{ce}/ρ is the coherent elastic scattering coefficient, μ_{ie}/ρ is the incoherent Compton elastic coefficient, μ_{is}/ρ is the inelastic Compton coefficient, and μ_p/ρ is the photoelectric coefficient. As designated previously, μ_a/ρ and μ/ρ are the energy absorption coefficient and the total attenuation coefficient.†

9-34 X-ray Energy Deposition and Shine Through Fluences

X-ray energy deposition in a thickness δ at a depth x due to direct fluence photons is given by

$$A'_{dir} = \varphi_o \left[1 - e^{-\left(\frac{\mu_a}{\rho}\right)\rho\delta}\right] e^{-\left(\frac{\mu}{\rho}\right)\rho x}.$$

If $\mu_a\delta << 1$, and if φ_o is in cal/cm^2, this expression can be written as

$$A'_{dir} = \varphi_o \left(\frac{\mu_a}{\rho}\right) \rho\delta \; e^{-\left(\frac{\mu}{\rho}\right)\rho x} \quad \text{cal/cm}^2.$$

† The symbols K, L_1, L_2, etc., in the tables and figures indicate the binding energies of the various electron shells (see paragraph 4-3, Chapter 4).

Frequently, the absorption is written in terms of cal/gm by dividing out the thickness $\rho\delta$,

$$A_{dir} = \varphi_o \left(\frac{\mu_a}{\rho}\right) e^{-\left(\frac{\mu}{\rho}\right)\rho x} \quad \text{cal/gm}.$$

This expression for the absorption is in terms of a dose; however, this assumes that very little of the flux is absorbed in the deposition region at depth x, i.e., the deposition region considered is very thin. Clearly, more energy than is in the incident flux cannot be absorbed.

The equation for direct fluence (φ_{dir}) given in paragraph 9-32 can be used to represent a small energy band of photons in X-ray energy spectra such as those tabulated in Table 4-3, Chapter 4, for various black body spectra. The total energy in the direct X-ray fluence after traversing thickness x is obtained by summing over the energy bands.

$$\varphi = \sum_i \varphi_{oi} \; e^{-\left(\frac{\mu}{\rho}\right)_i \rho x} \quad \text{cal/cm}^2.$$

In a like manner, the total direct fluence X-ray energy absorption at depth ρx is obtained by summing for each energy band.

$$A = \sum_i \left(\frac{\mu_a}{\rho}\right)_i \varphi_{oi} \; e^{-\left(\frac{\mu}{\rho}\right)_i \rho x} \quad \text{cal/cm}^2.$$

Problems 9-3 and 9-4 illustrate how these equations can be used to calculate approximate values for energy deposition and shine through.

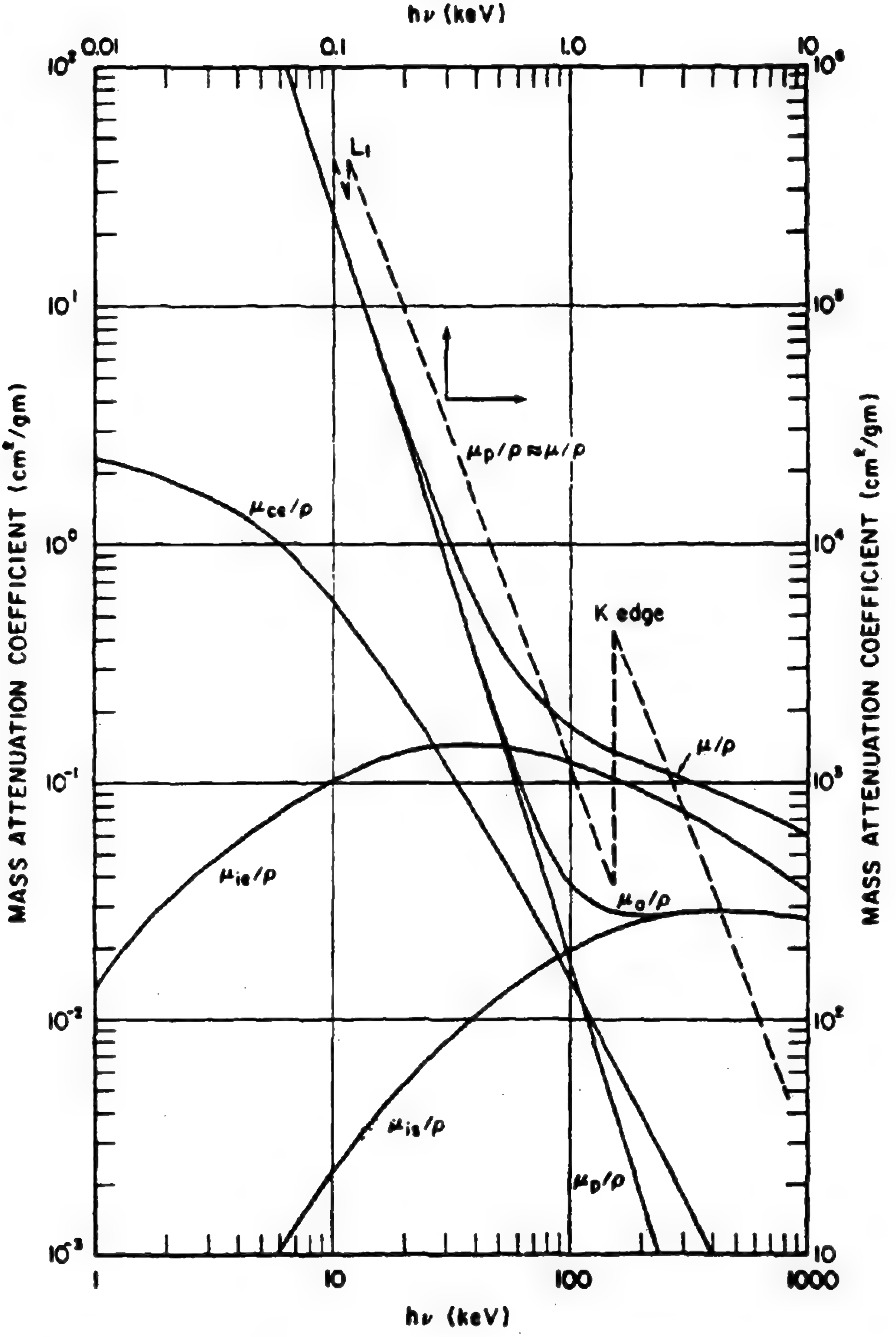


Figure 9-28. Photon Cross Sections in Aluminum

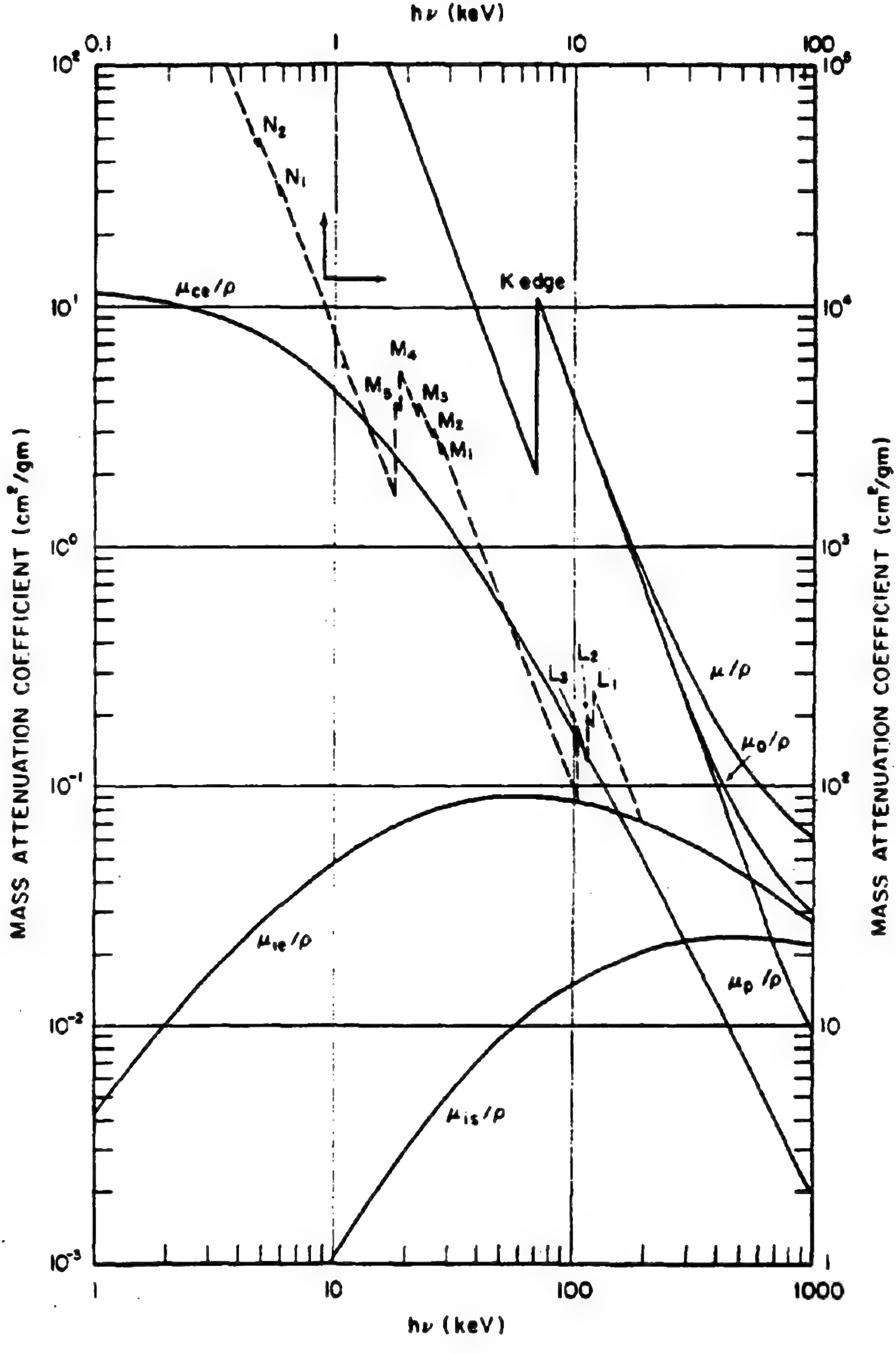


Figure 9-31. Photon Cross Sections in Tungsten

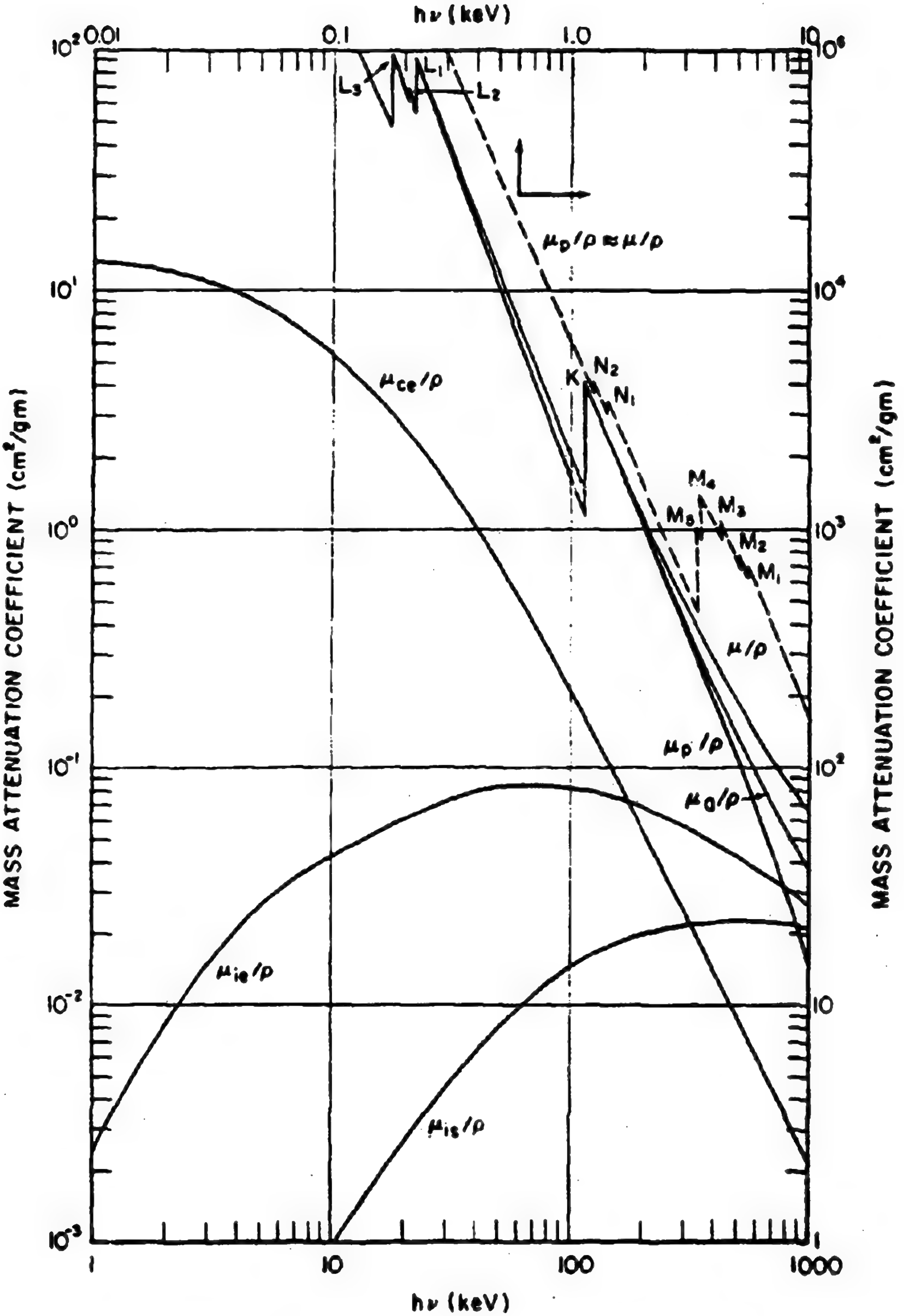


Figure 9-32. Photon Cross Sections in Uranium

9-35 X-ray Energy Deposition Summary

The methods described in paragraphs 9-33 and 9-34 and illustrated in Problems 9-3 and 9-4 allow the calculation of curves that show approximations of energy deposition as a function of depth for black body spectra incident on any material, if the cross sections are known for the material.

INITIAL PRESSURIZATION OF MATERIALS DUE TO X-RAY DEPOSITION

An immediate consequence of the deposition of X-ray energy is the rapid heating of the material. This heating causes an initial pressure distribution as a function of depth in the structure. The initial pressurization generates shock waves that propagate through the thickness of the shell of the structure. The heating can result in a solid material changing phase, that is, melting or vaporizing. The melting and vaporization cause blowoff, which imparts an impulse to the structure and excites whole structure modes of response.

9-36 Phase Changes Induced by X-ray Heating

In most nuclear weapon X-ray environments, the X-ray energy is deposited in a very short time, a few nanoseconds to a few hundred nanoseconds. The material cannot expand appreciably during this time, so the energy deposition process can be considered to occur at a constant volume or at normal material density, ρ_0. Rapid melting and vaporization are accompanied by enormous pressure increases. Values

for enthalpy changes for melting and vaporization for the metals discussed in the previous subsection are given in Table 9-17. These values are for one atmosphere pressure. In most X-ray problems of interest the material is initially at very high pressure, so these values can be considered to be only approximate. This approach is not correct for ablators as a class although it might apply to carbon phenolic in a cold environment. Confining the discussion to metals will not restrict the transfer of principles.*

[redacted] The rising pressure that results from heating at constant density is illustrated in Figures 9-39 and 9-40 where isoenergy lines of aluminum are shown in pressure-density plots. If the internal energy is above the critical energy, 3,016 cal/gm for aluminum, the material can be considered as a vapor. Figure 9-40 shows the high pressure, high energy intercepts with the normal density abscissa (ρ_0 = 2.7 gm/cm^3). The release adiabats for expansion from density ρ_0 to low density and pressure also are shown in this figure. Expansion along the adiabat results in decreasing internal or potential energy as the material develops kinetic energy during "blowoff." For example, a 6,000 cal/gm energy deposition in aluminum at ρ_0 = 2.7 gm/cm^3 results in a pressure of about 1.5 megabars (Mb). The aluminum would expand from that state to low pressure and density, with final internal energy of about 3,000 cal/gm and about 3,000 cal/gm of kinetic energy. The 3,000 cal/gm of internal or potential energy is used to overcome the physical and chemical forces that bind the atoms together in the solid. This leads to the concept of heat of sublimation. The heat of sublimation at absolute zero, E_{so}, is the energy required to form the saturated vapor from the solid at a temperature of absolute zero. Thus, E_{so} does not include any energy of kinetic motion. The energy of sublimation generally is a function of temperature becoming larger for larger deposition energies (temperatures).

*[redacted] The problem of phase changes in a composite heat shield ablator is more complicated since different deposition profiles, material enthalpy, and thermal conductivities are involved in the calculations. While some materials, e.g., tape-wrapped carbon phenolic, may behave like metals in a cold environment, the techniques described here generally are not applicable to the description of the blowoff process in the broad category of composite materials that use three dimension (3-D) weaves for heat shields or for X-ray shields that use dispersed high Z materials for loading.

Table 9-17. [redacted] Enthalpy Change for Selected Metals [redacted]
(cal/gm)

Metal-Atomic Weight	To Melt	Through Melt	To Vapor	Through Vapor	Sublimation Energy
Be 9.013	876.0	1,187.0	2,147.0	10,040.0	8,682.0
Al 26.98	160.4	255.3	771.1	3,347.0	2,891.0
Fe 55.85	250.8	315.8	573.0	2,071.0	1,782.0
Cu 63.54	110.0	160.0	336.0	1,481.0	1,275.0
W 183.85	153.9	200.0	304.0	1,353.0	1,110.0
U 238.00	49.0	64.5	171.9	596.1	492.1

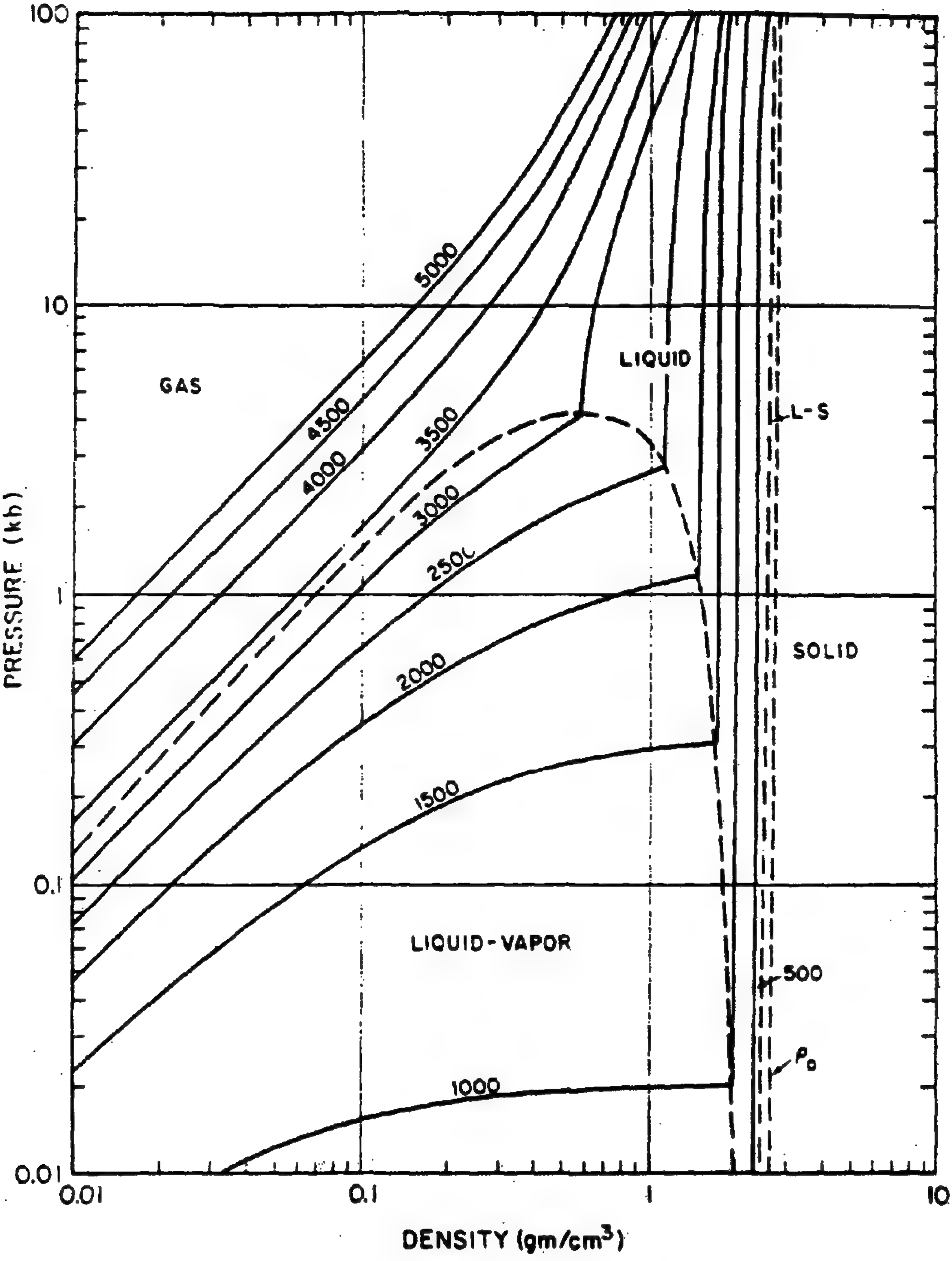


Figure 9-39. Aluminum Isoenergy Lines.
Parameter is Energy in cal/gm

The units for ϵ in the equation given above are energy per unit volume, which have the same dimensions as pressure. Therefore, the energy required in cal/gm for a phase change can be expressed in units of pressure, if the density of the material is specified. If the internal energy, E, is given per unit mass, the relation to ϵ is

$$\epsilon \ (\text{cal/cm}^3) = E \ (\text{cal/gm}) \ \rho_o (\text{gm/cm}^3).$$

The value of ϵ in megabars may then be obtained by the relation

$$\epsilon \ (\text{Mb}) = \epsilon \ (\text{cal/cm}^3) \times 4.18 \times 10^7 \left(\frac{\text{erg}}{\text{cal}}\right) \times 1 \left(\frac{\text{dyne} \cdot \text{cm}}{\text{erg}}\right) \times 1 \left(\frac{\text{Mb}}{10^{12} \ \text{dyne/cm}^2}\right)$$

$$\epsilon \ (\text{Mb}) = 4.8 \times 10^{-5} \ \epsilon \left(\frac{\text{cal}}{\text{cm}^3}\right)$$

$$= 4.18 \times 10^{-5} \ \rho_o E \left(\frac{\text{cal}}{\text{gm}}\right).$$

Thus, the previous equation for pressure may be written

$$P \ (\text{Mb}) = G \frac{\rho}{\rho_o} \epsilon \ (\text{Mb}),$$

or

$$P \ (\text{Mb}) = 4.18 \times 10^{-5} \ G\rho \ E \ (\text{cal/gm}).$$

The enthalpy changes of the metals shown in Table 9-17 in cal/gm are given in Table 9-19.

Table 9-19. [redacted] Enthalpy Changes ϵ (Mb) [redacted]

Metal	ρ_o (gm/cm^3)	To Melt	Through Melt	To Vapor	Through Vapor	Sublimation Energy, E_s
Be	1.85	0.068	0.0918	0.166	0.776	0.671
Al	2.70	0.0181	0.0288	0.087	0.378	0.326
Fe	7.86	0.0824	0.1036	0.188	0.680	0.585
Cu	8.92	0.0410	0.0596	0.125	0.552	0.475
W	19.3	0.124	0.161	0.245	1.092	0.895
U	18.7	0.0383	0.0504	0.134	0.466	0.385

Table 9-20. Pressure Change, P (Mb)
($\rho = \rho_o$, $\eta = 1$)

Metal	G	To Melt	Through Melt	To Vapor	Through Vapor	Sublimation Energy, E_s
Be	1.45	0.099	0.133	0.241	0.12	0.973
Al	2.13	0.0366	0.0613	0.185	0.805	0.694
Fe	1.69	0.139	0.175	0.318	1.15	0.989
Cu	2.00	0.082	0.119	0.250	1.10	0.950
W	1.43	0.177	0.230	0.350	1.56	1.28
U	2.03	0.076	0.102	0.273	0.946	0.782

The pressures associated with these changes at ambient density, i.e., when $\rho = \rho_o$, and P (Mb) = $G\epsilon$ (Mb), are shown in Table 9-20.

From Table 9-20, aluminum has a sublimation pressure of about 0.7 Mb at ambient density, corresponding to sublimation energy of about 2,900 cal/gm (Table 9-17). This point is shown in Figure 9-40, labeled E_s at about 3,000 cal/gm. Table 9-20 indicates that the pressures associated with vaporization of metals at ambient density are with some exceptions about 1 Mb. A survey of more than 30 common metal elements indicates that an average of 1 Mb for vaporization is a good approximation, especially if the Grüneisen value for the material is uncertain. Since a bar corresponds to 14.7 psi a Mb is the enormous pressure of about 1.45×10^7 psi. Thus, tremendous forces are involved in the pressure gradients associated with metal vaporization at ambient density. Table 9-17 shows that vaporization usually involves several thousand calories per gram of energy. High explosive materials (TNT, etc.) release about 1,000 cal/gm. Therefore, on a mass basis there is more energy associated with metal vaporization than with high explosives. Generally, the thicknesses of material evaporated by X-ray absorption is small, and, the total mass of material that is vaporized generally is small.

SHOCK WAVE PROPAGATION AND DAMAGE PREDICTIONS

The sequence of events for the generation and propagation of a stress wave through the thickness of an aerospace shell and the damage produced is illustrated in Figure 9-41. Cold X-rays are deposited primarily in a relatively thin sheet of material at the front surface (Figure 9-41a). After the energy is deposited a compression wave propagates inward from the front surface, followed by a rarefaction that causes the vapor and liquid to blow off (Figure 9-41b). This rarefaction also may cause a spall of solid material from the front surface (Figure 9-41c). Later the compression wave reflects from the back surface and returns as a rarefaction wave. This rarefaction wave, or the coincidence of this wave with the rearward moving rarefaction may cause the rear surface to spall (Figure 9-41d), or may cause fracturing or debonding. This process occurs within the order of a microsecond and generally is complete before the overall structural motion occurs. The shock effects are

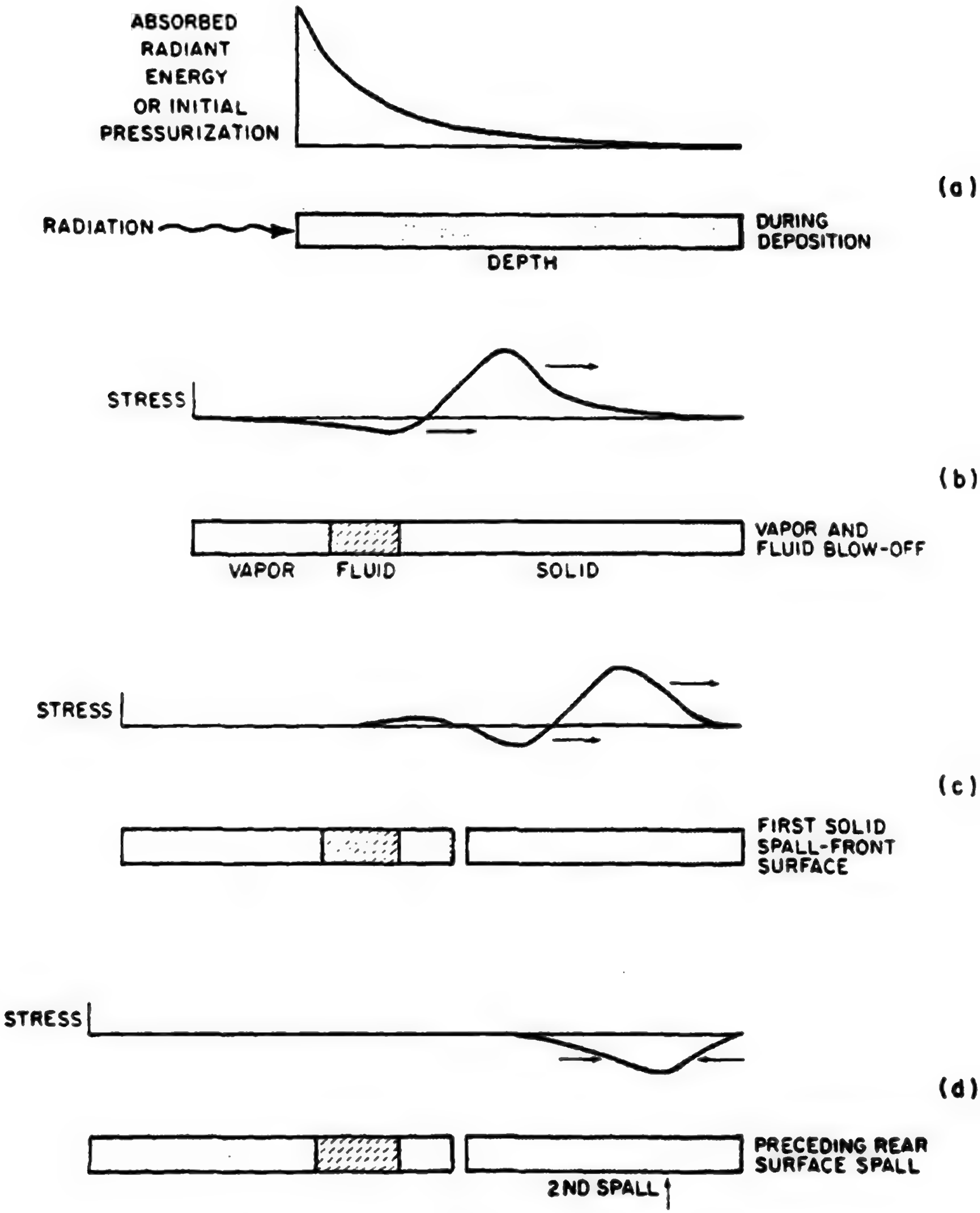
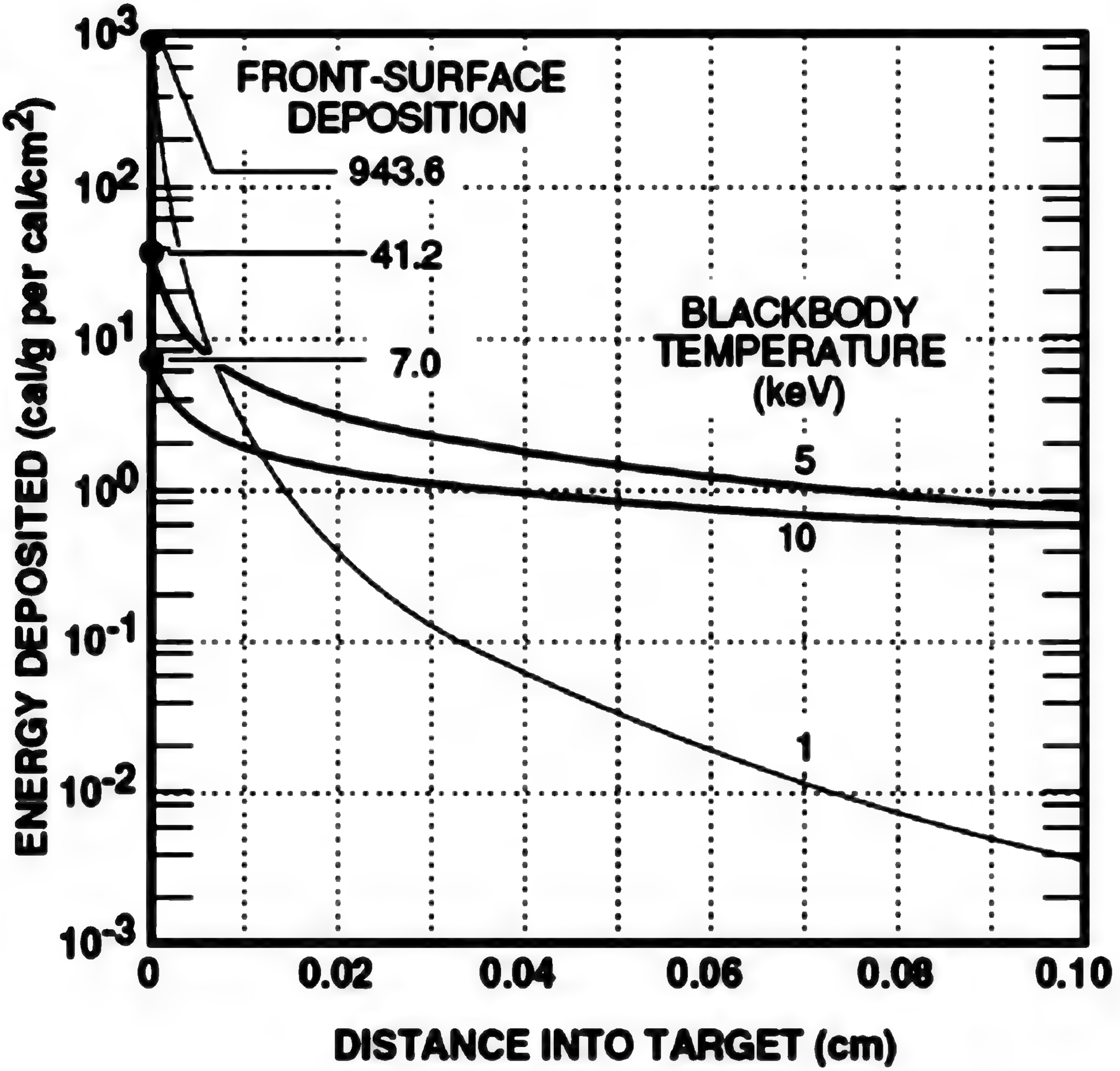


Figure 9-41. Sequence of Spallation Following Radiation Deposition



(IMAGE RESTORED TO DELETED IMAGE OF 1989 DECLASSIFIED VERSION OF EM-1 USING THE DECLASSIFIED VERSION OF DIAGRAM IN THE 1996 UNCLASSIFIED JOHN NORTHROP EM-1 EXTRACTS HANDBOOK.)

Figure 9-35. [redacted] Energy Deposited in Aluminum by Black Body Spectra [redacted]

Table 5-3. Representative Types of Nuclear Weapons

Type	Description
I	Subkiloton Fission
II	Pure Fission Implosion
III	Large (physically) Boosted Fission
IV	Small (physically) Boosted Fission
V	Enhanced Neutron Weapon
VI	Gun-Assembly Fission Weapon
VII	Thermonuclear Weapon
VIII	Thermonuclear Weapon

Table 5-1. Weapon Neutron Output Spectra

Neutron Energy (MeV)	Fission Weapon (neutrons/kt)	Thermonuclear Weapon (neutrons/kt)
12.2 -15.0		1.62×10^{22}
10.0 -12.2		8.53×10^{21}
8.18 -10.0	7.32×10^{20}	6.08×10^{21}
6.36 - 8.18	1.27×10^{21}	5.46×10^{21}
4.06 - 6.36	3.00×10^{21}	6.41×10^{21}
2.35 - 4.06	8.90×10^{21}	1.22×10^{22}
1.11 - 2.35	2.52×10^{22}	2.84×10^{22}
0.111 - 1.11	3.84×10^{22}	6.18×10^{22}
0.0033- 0.111	2.22×10^{22}	1.71×10^{23}
Total	9.97×10^{22}	3.16×10^{23}

These spectra are those that were used in the calculation of dose to personnel from weapon types II and VIII, respectively.

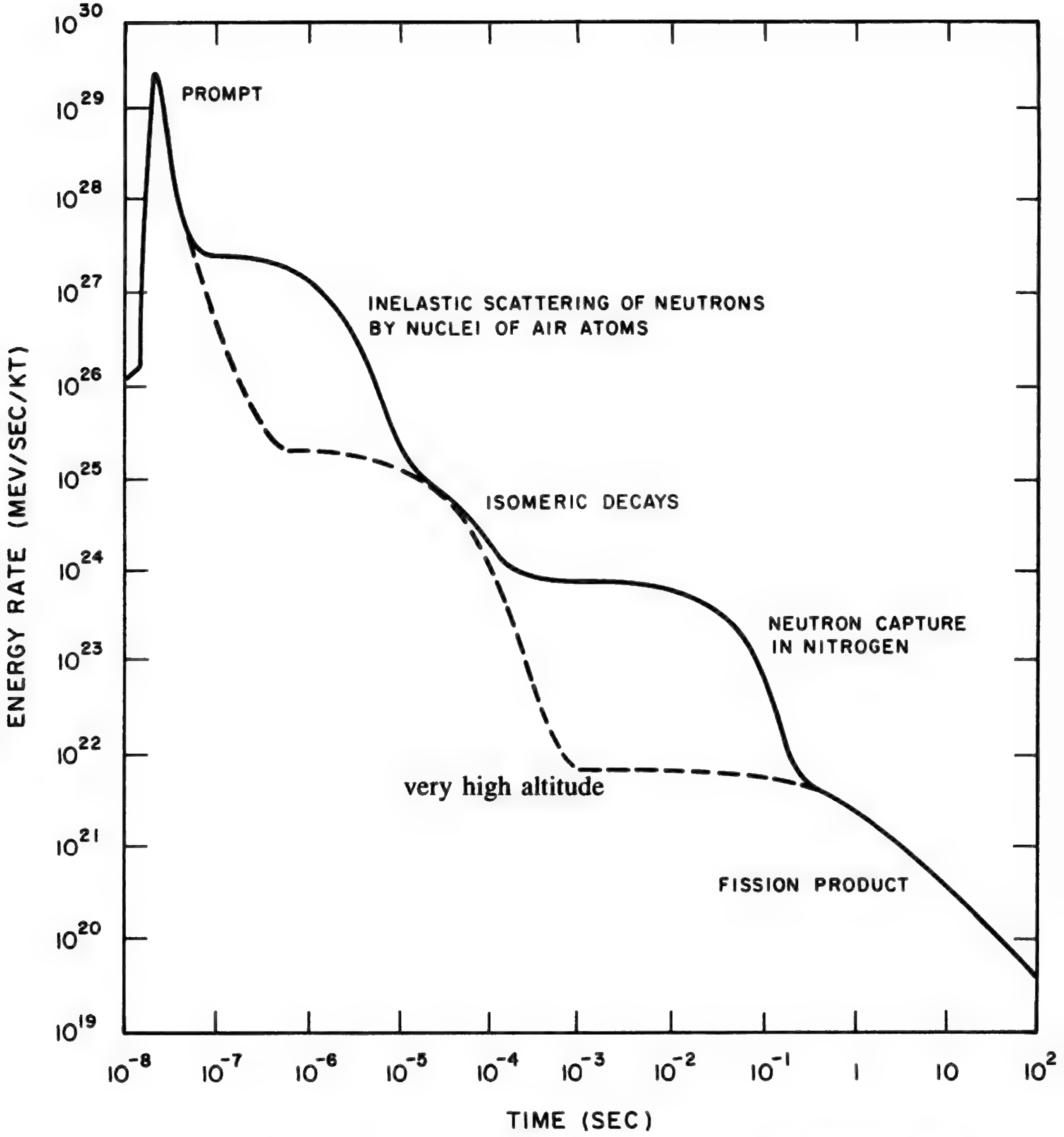


Figure 5-8. Calculated Time Dependence of the Gamma Ray Output from a Large Yield Explosion, Normalized to 1 kt

Table 9-26. [redacted] Failure Thresholds for Typical MOS Digital Microcircuits [redacted]

Designation	Function	Failure Level: Gamma, (rads (Si))	Failure Level: Neutron,* (n/cm^2)
SC 1171	NAND gate	2 x 10^5†	–
MEM 529	Binary element	1.4 x 10^5‡	–
SC 1171	Binary element	1. 10^5‡	–
MEM 501	Shift register	1. x 10^5§	–
MEM 590	Chopper	Not measured**	3 x 10^{14}
SC 1149	Flip-Flop	Not measured**	8 x 10^{14}
MC 1155	AND/OR gate	2 x 10^5 (Cobalt-60)††	
3300	25-bit static shift register	>5 x 10^3 (FXR)‡‡ >8 x 10^4 (TRIGA)‡‡	
3003	100-bit shift register	>2 x 10^4 (FXR)‡‡ >5 x 10^4 (TRIGA)‡‡	
1406	100-bit shift register	>10^5 (FXR)‡‡ <2.5 x 10^4 (TRIGA)	
1101	256-random access memory	4 x 10^4 (FXR) 2 x 10^4 (TRIGA)	3 x 10^{11}

* [redacted] Neutron fluence specified as (E > 10 keV, fission).
† [redacted] Supply voltage – 20 volts.
‡ [redacted] Supply voltage – 15 volts.
§ [redacted] Clock voltage – 10 volts.
** [redacted] Supply voltage – 10 volts.
†† [redacted] Type of facility in which test was performed.
‡‡ [redacted] No failures at these levels.

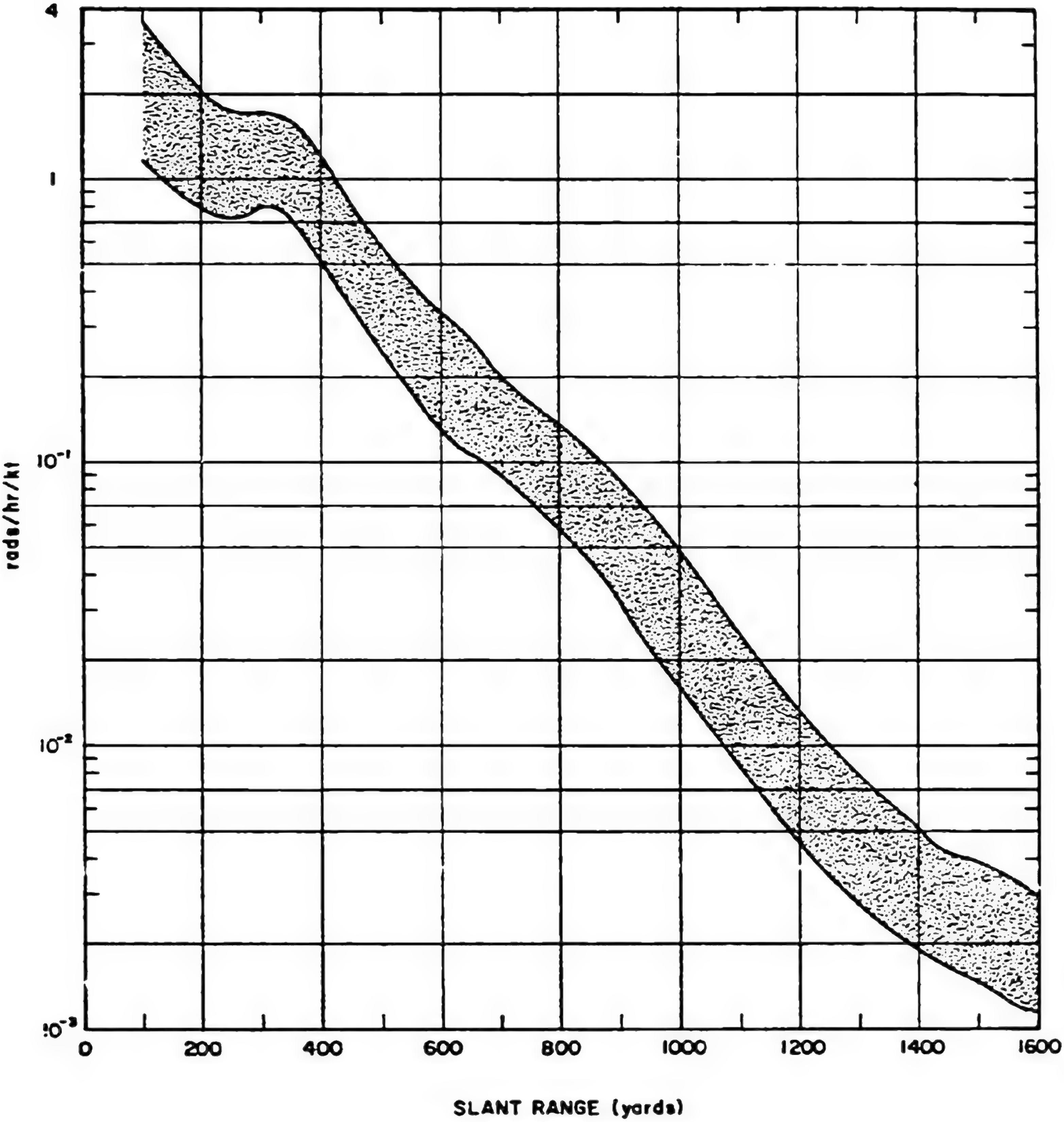


Figure 5-18. Neutron-Induced Gamma Dose Rate as a Function of Slant Range at a Reference Time of 1 Hour After Burst LIBERIA SOIL

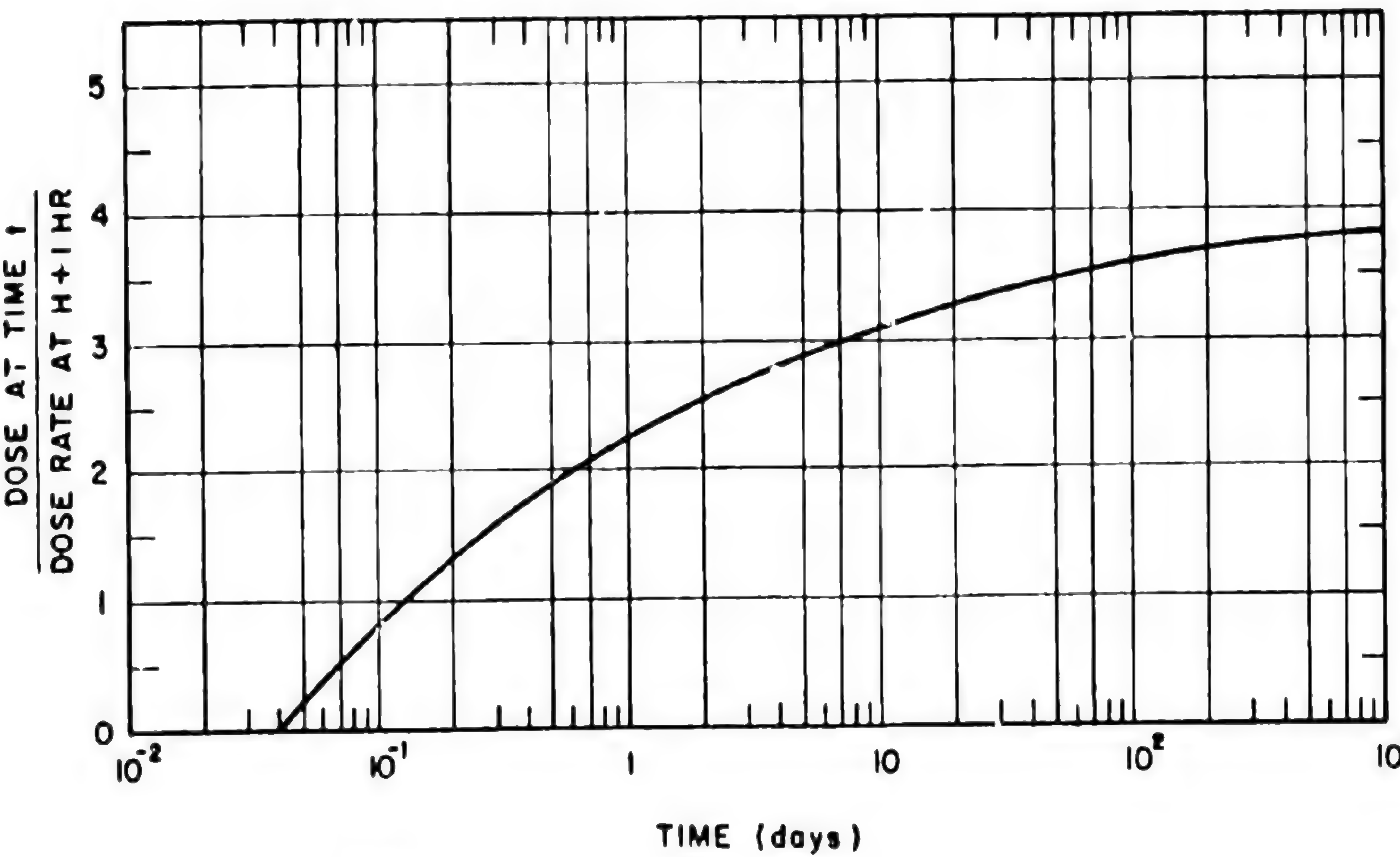


Figure 5-41. [redacted] Normalized Dose Accumulated in a Fallout Contaminated Area from H + 1 Hour to H + 1,000 Days [redacted]

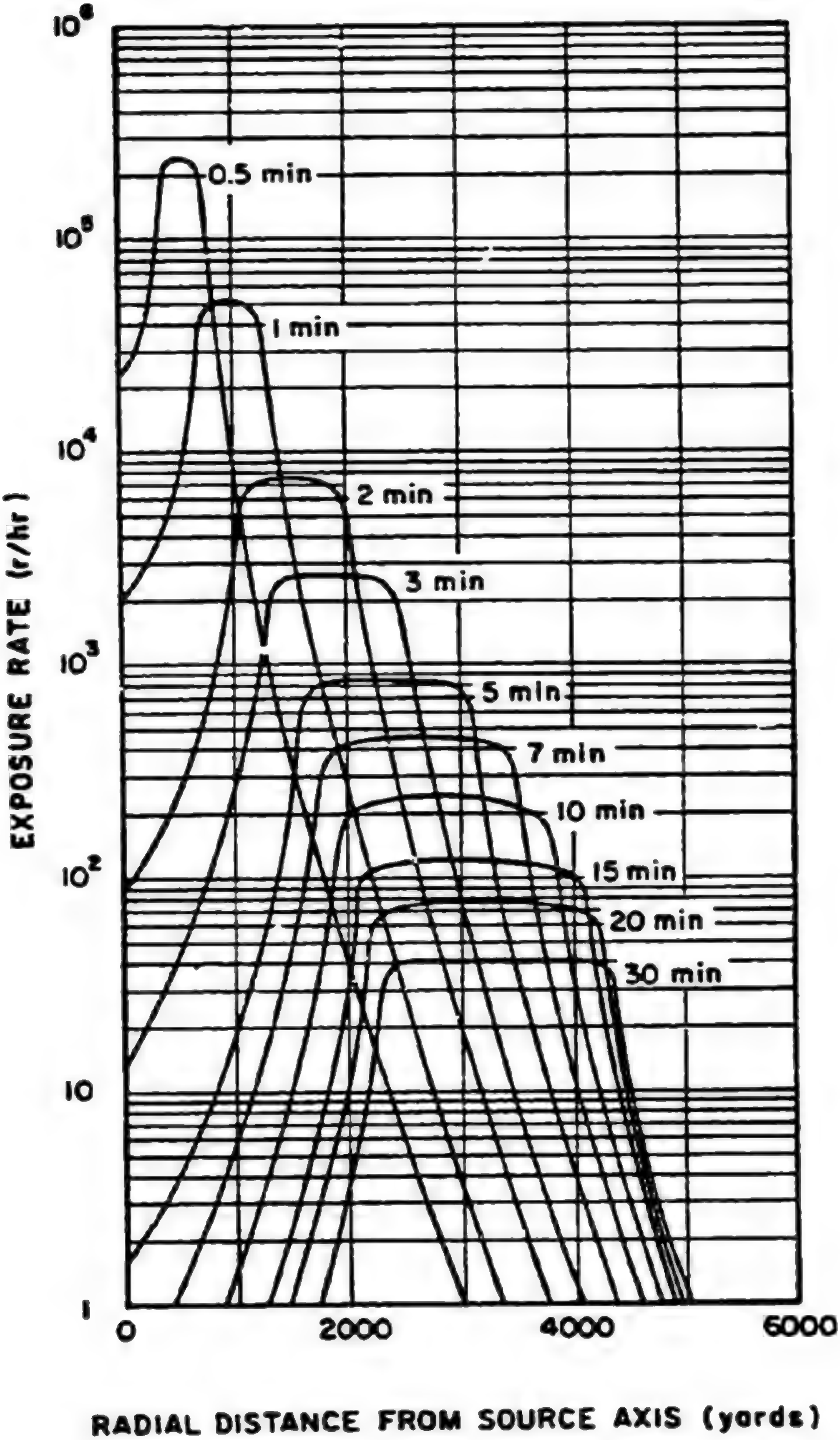


Figure 5-47. [redacted] Base Surge Radiation Exposure Rate 15 Feet Above the Water Surface from a 10 kt Explosion on the Bottom in 65 Feet of Water, No-Wind Environment [redacted]

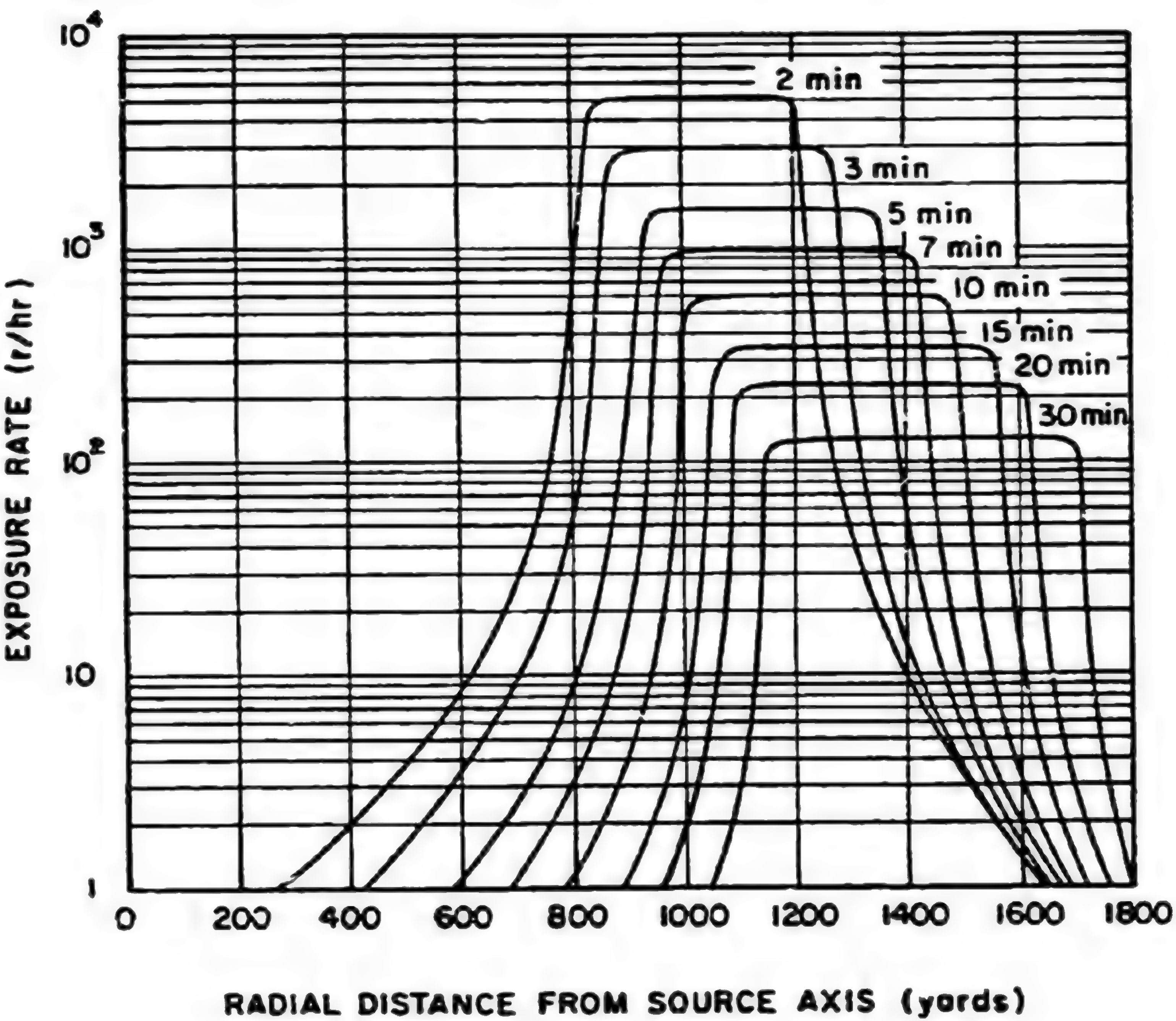


Figure 5-53. Pool Radiation Exposure Rate 15 Feet Above the Water Surface from a 10 kt Explosion on the Bottom in 65 Feet of Water, No-Current Environment

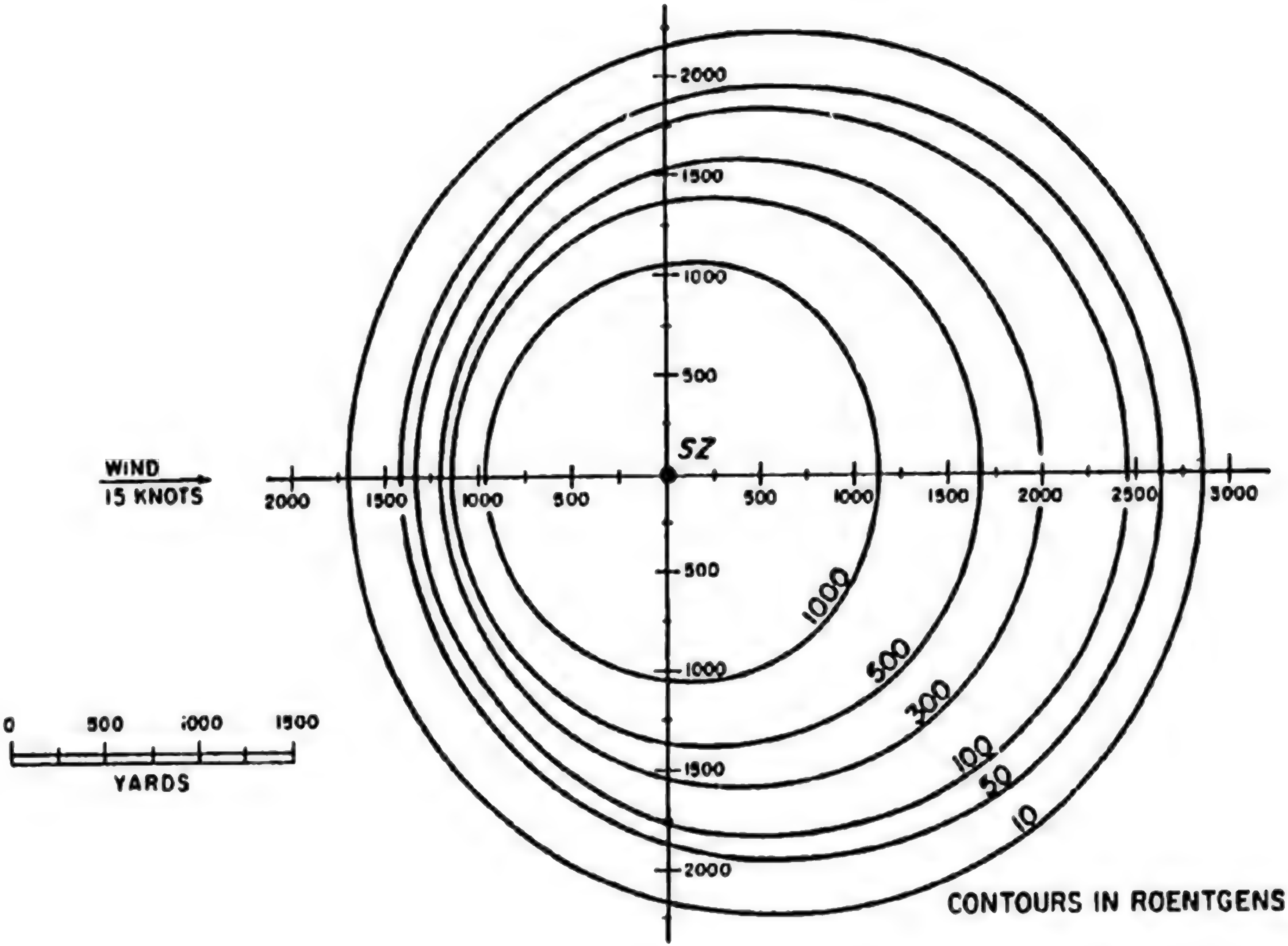


Figure 6-70. Two-Minute Total Exposure 16 Feet Above the Water Surface from 10 kt Explosion at a Depth of 500 Feet In 6,000 Feet of Water, 15 Knot Wind, No-Current Environment

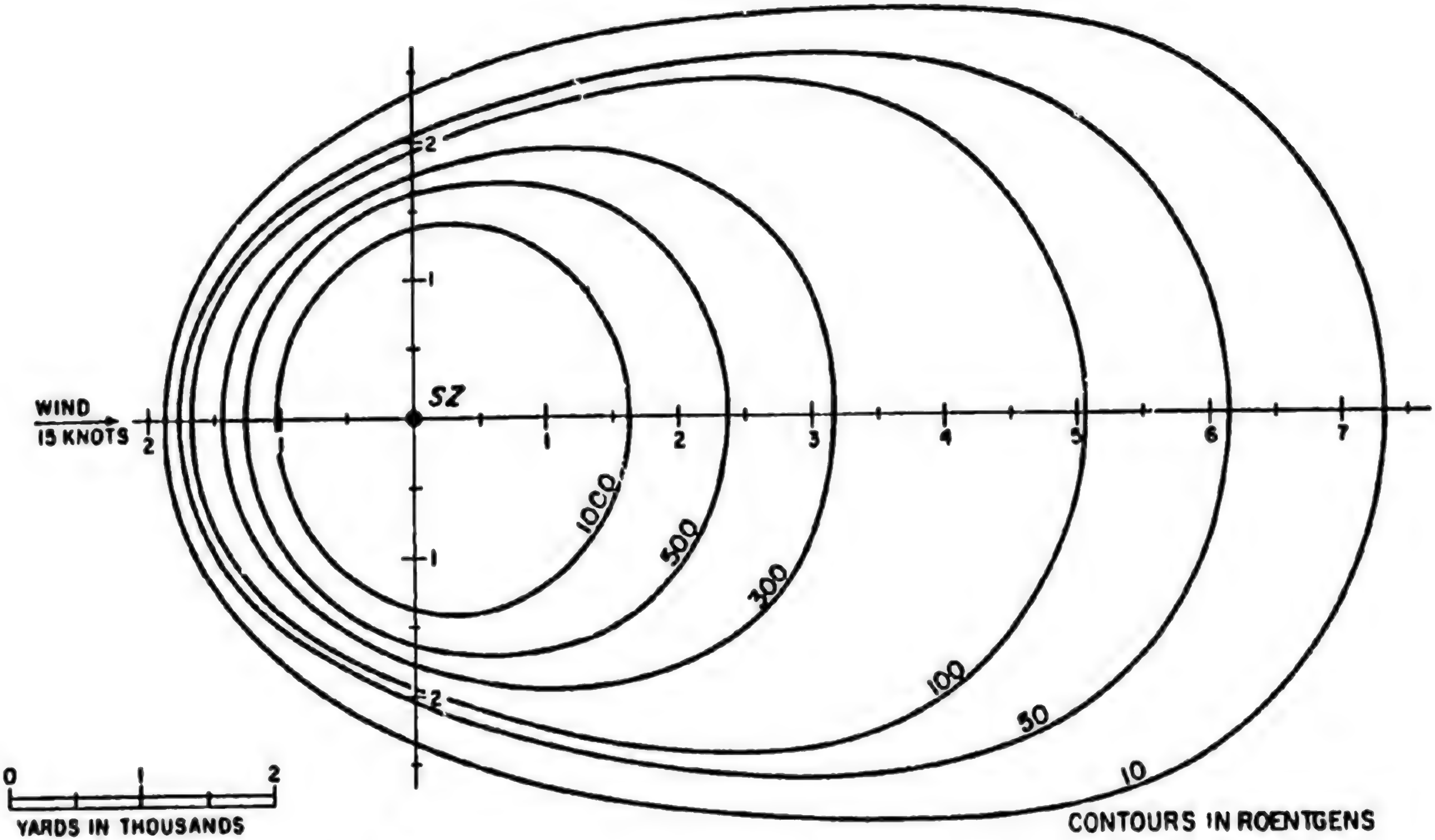


Figure 5-71. [redacted] Ten-Minute Total Exposure 15 Feet Above the Water Surface from a 10 kt Explosion at a Depth of 500 Feet in 5,000 Feet of Water, 15 Knot Wind, No-Current Environment [redacted]

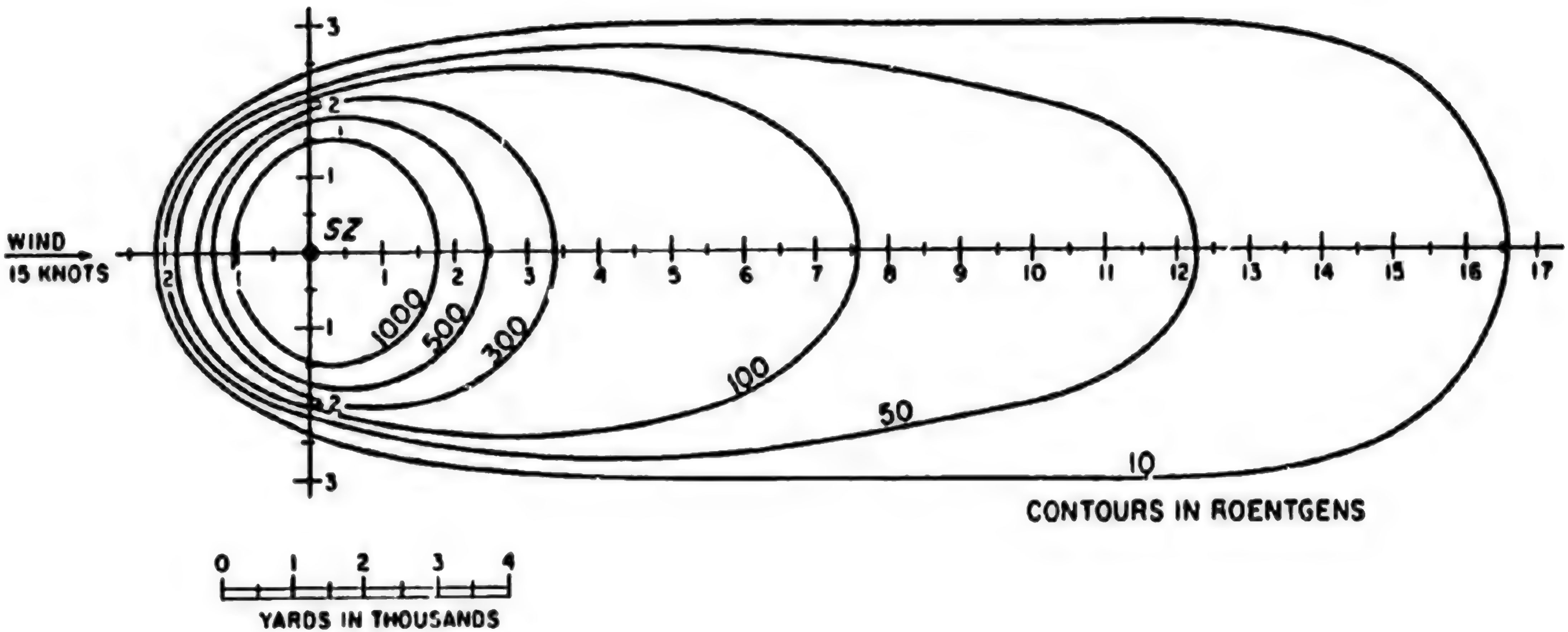


Figure 5-72. [redacted] Thirty-Minute Total Exposure 15 Feet Above the Water Surface from a 10 kt Explosion at a Depth of 500 Feet in 5,000 Feet of Water, 15 Knot Wind, No-Current Environment [redacted]

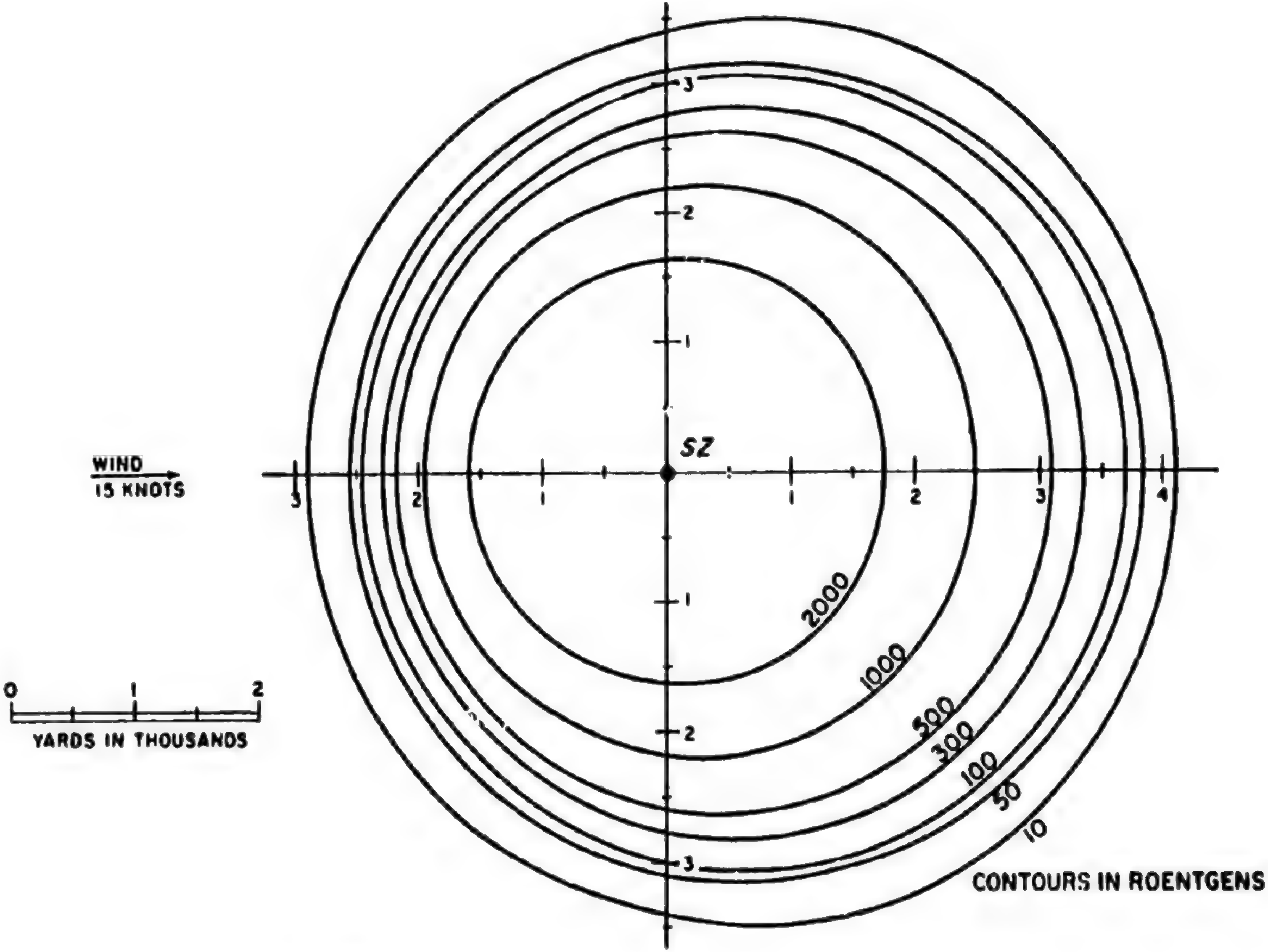


Figure 5-73. [redacted] Two-Minute Total Exposure 15 Feet Above the Water Surface from a 100 kt Explosion at a Depth of 890 Feet in 5,000 Feet of Water, 15 Knot Wind, No-Current Environment [redacted]

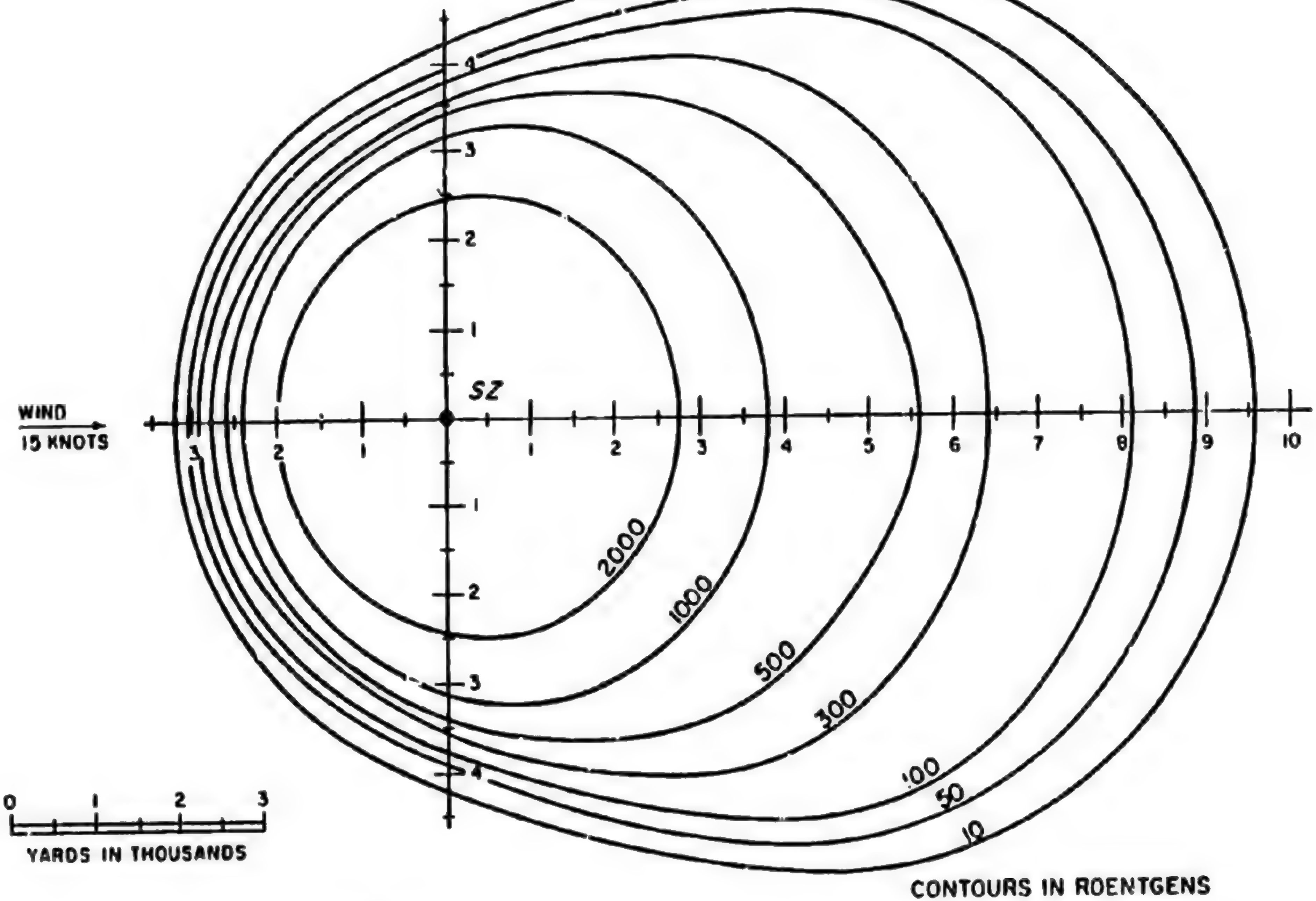


Figure 5-74. [redacted] Ten-Minute Total Exposure 15 Feet Above the Water Surface from a 100 kt Explosion at a Depth of 890 Feet in 5,000 Feet of Water, 15 Knot Wind, No-Current Environment [redacted]

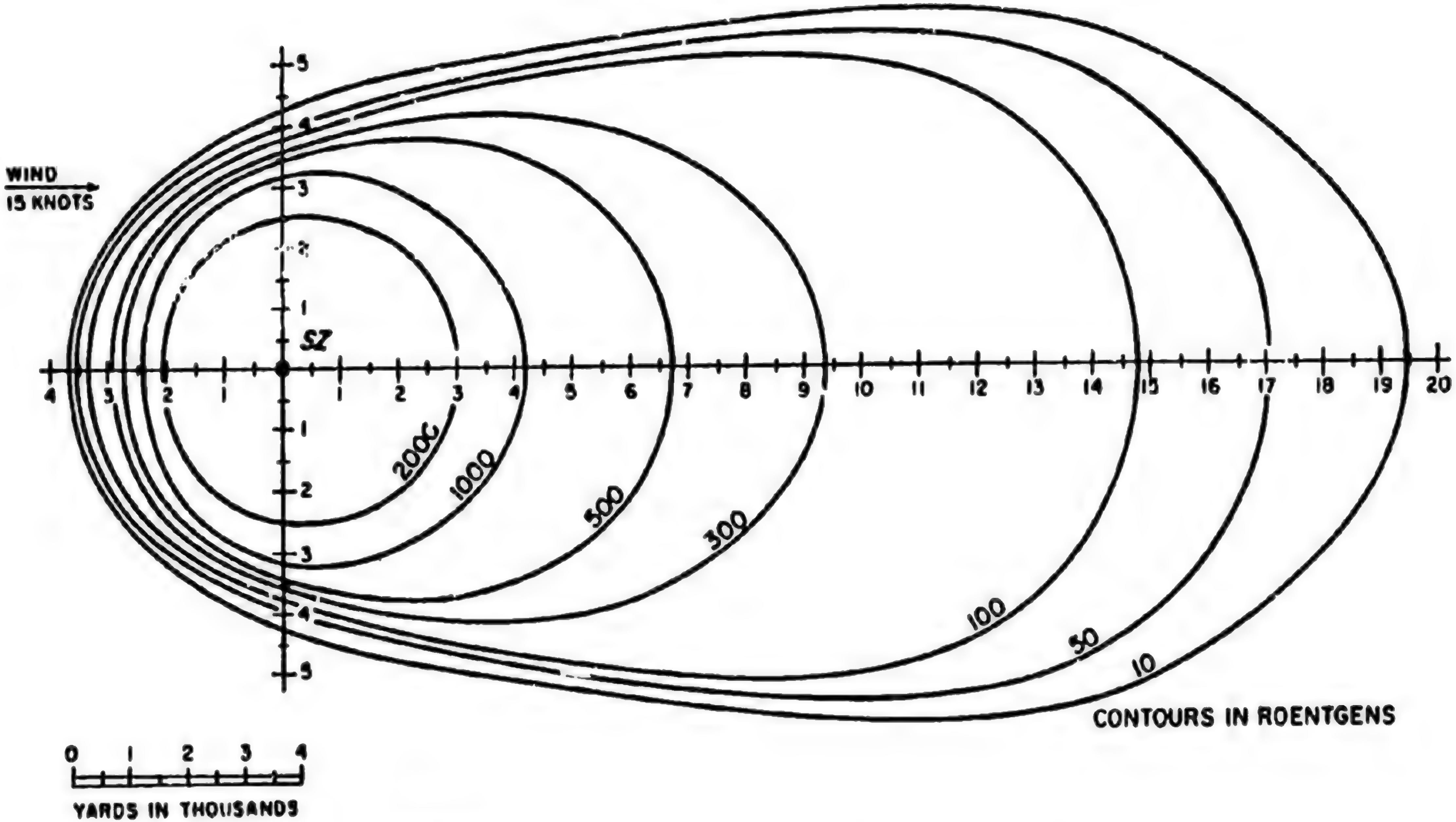


Figure 6-75. [redacted] Thirty-Minute Total Exposure 15 Feet Above the Water Surface from a 100 kt Explosion at a Depth of 890 Feet in 5,000 Feet of Water, 15 Knot Wind, No-Current Environment [redacted]

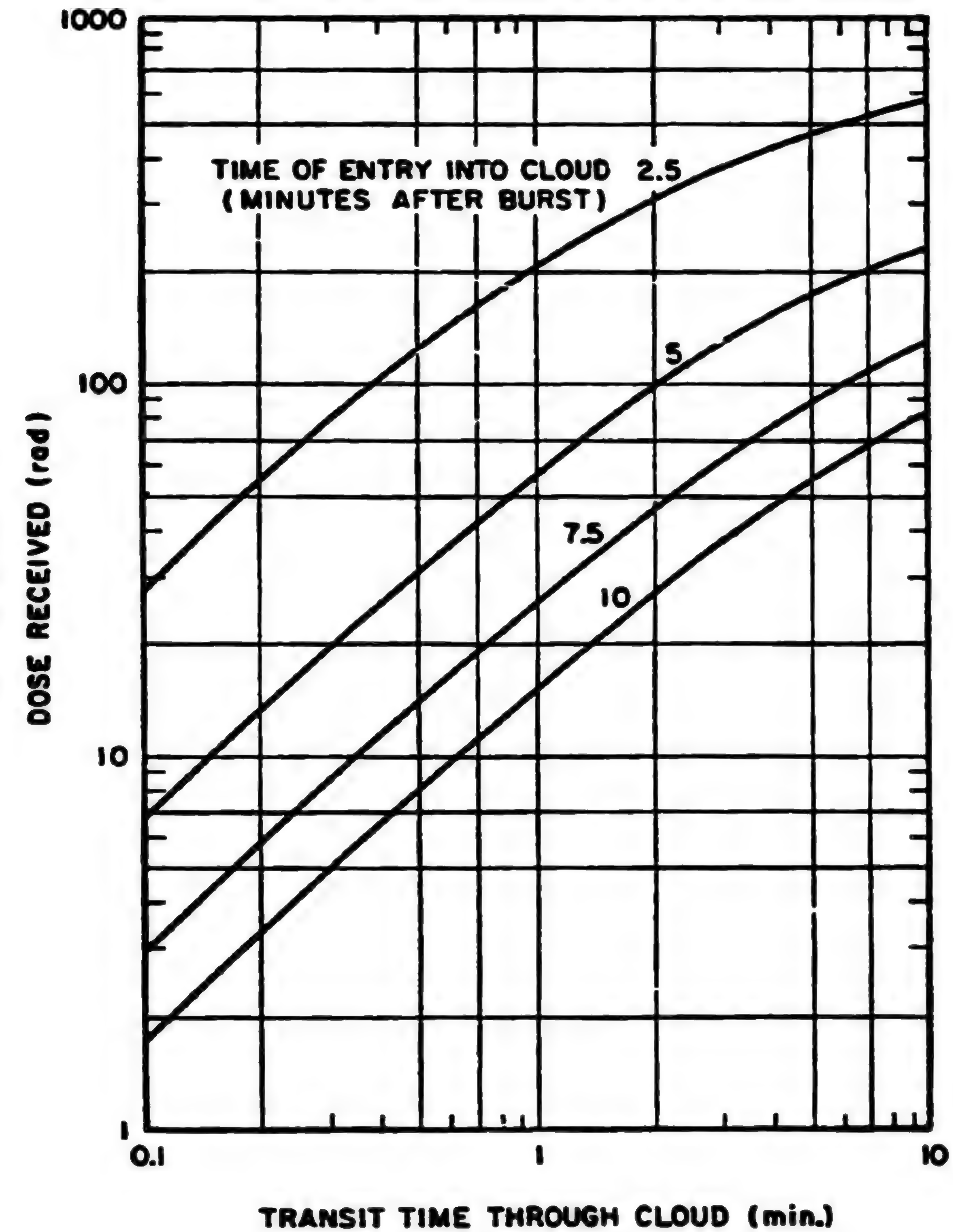
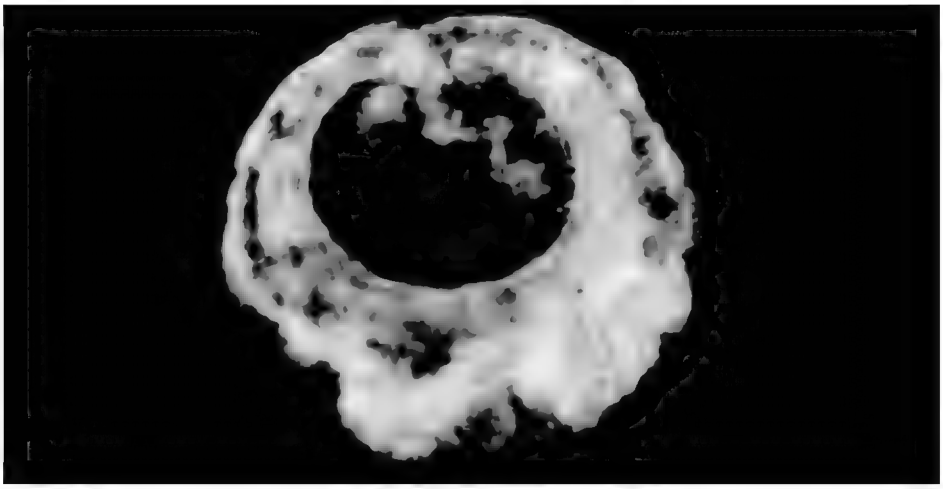


Figure 5-79. Dose Received While Flying Through a Nuclear Cloud as a Function of Transit Time Through the Cloud



(a) Blue Gill Taken From Burst Locale

50 km altitude

(b) Teak Taken From Maui (1300 km Away)

77 km altitude

(c) Check Mate Taken From Burst Locale

147 km altitude

The length along the geomagnetic field is about 1,000 kilofeet. The heated air within the fireball is highly ionized, with many striations oriented along the geomagnetic field. (The dark spots within the fireball are rocket trails.)

Figure 1-4. Photographs of High Altitude Bursts, t = 100 sec

Chapter 7

ELECTROMAGNETIC PULSE (EMP) PHENOMENA

The nuclear electromagnetic pulse (EMP) is the time-varying electromagnetic radiation resulting from a nuclear burst. It has a very broad frequency spectrum, ranging from near dc to several hundred MHz.

The generation of EMP from a nuclear detonation was predicted even before the initial test, but the extent and potentially serious degree of EMP effects were not realized for many years. Attention slowly began to focus on EMP as a probable cause of malfunction of electronic equipment during the early 1950s. Induced currents and voltages caused unexpected equipment failures during nuclear tests, and subsequent analysis disclosed the role of EMP in such failures. Finally in 1960 the possible vulnerability of hardened weapon systems to EMP was officially recognized. Increased knowledge of the electric and magnetic fields became desirable for both weapons diagnostics and long-range detection of nuclear detonations. For all these reasons a more thorough investigation of EMP was undertaken.

Theoretical and experimental efforts were expanded to study and observe EMP phenomenology and to develop appropriate descriptive models. A limited amount of data had been gathered on the phenomenon and its threat to military systems when all aboveground testing was halted in 1962. From this time reliance has been placed on underground testing, analysis of existing atmospheric test data, and nonnuclear simulation for experimental knowledge. Extended efforts have been made to improve theoretical models and to develop associated computer codes for predictive studies. At the same time, efforts to develop simulators capable of producing threat-level pulses for system coupling and response studies have been expanded.

This chapter describes the EMP generation mechanism and the resulting environment for various burst regimes. The description is largely qualitative, since the complexity of the calculations requires that heavy reliance be placed on computer code calculations for specific problems. Some results of computer code calculations are presented, but generalization of these results is beyond the scope of this chapter. More complete treatments of the EMP phenomena may be found in the "DNA EMP (Electromagnetic Pulse) Handbook (U)" (see bibliography).

ENVIRONMENT – GENERAL DESCRIPTION

7-1 Weapon Gamma Radiation

The gamma radiation output from a nuclear burst initiates the processes that shape the development of an electromagnetic pulse. The gamma radiation components important in EMP generation are the prompt, air inelastic, and isomeric gammas (see Chapter 5). Briefly, the prompt gammas arise from the fission or fusion reactions taking place in the bomb and from the inelastic collisions of neutrons with the weapon materials. The fraction of the total weapon energy that may be contained in the prompt gammas will vary nominally from about 0.1% for high yield weapons to about 0.5% for low yield weapons, depending on weapon design and size. Special designs might increase the gamma fraction, whereas massive, inefficient designs would decrease it.

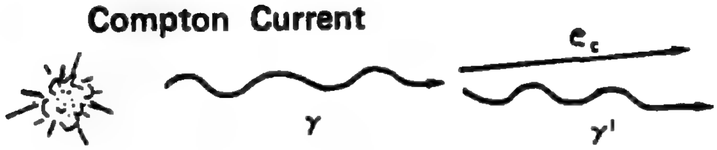


Figure 7-1. (U) The Compton Effect (U)

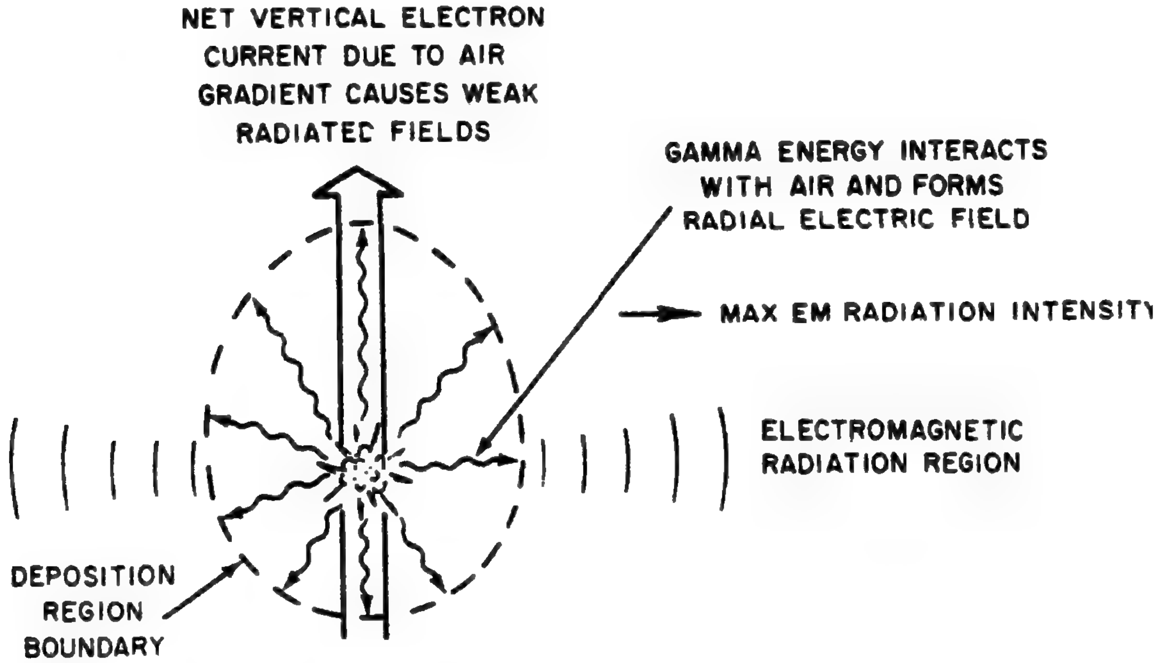


Figure 7-6. Simple Illustration of Air-Burst EMP

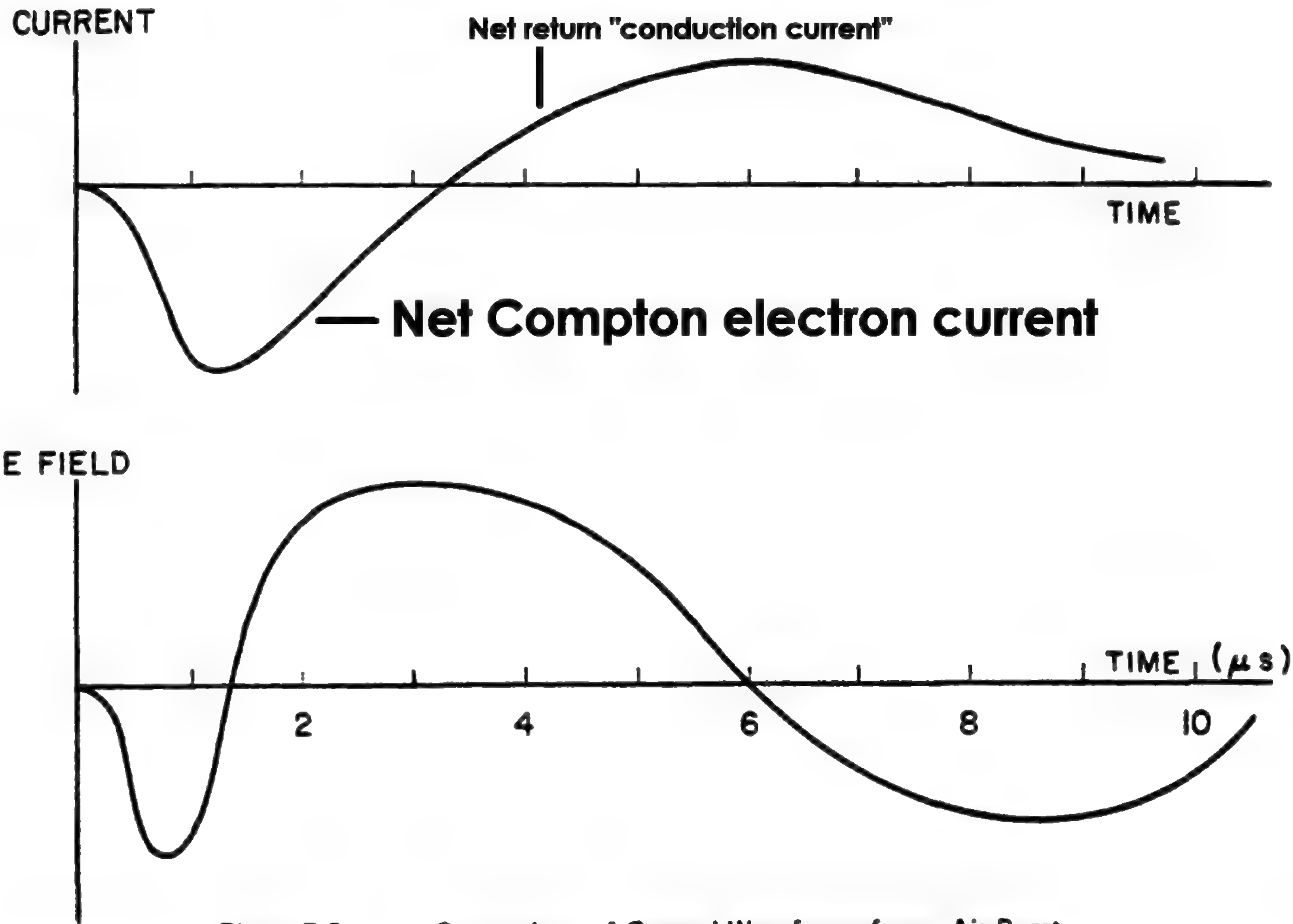


Figure 7-8 Comparison of General Waveforms for an Air Burst

Radiated field is proportional to time-derivative of current

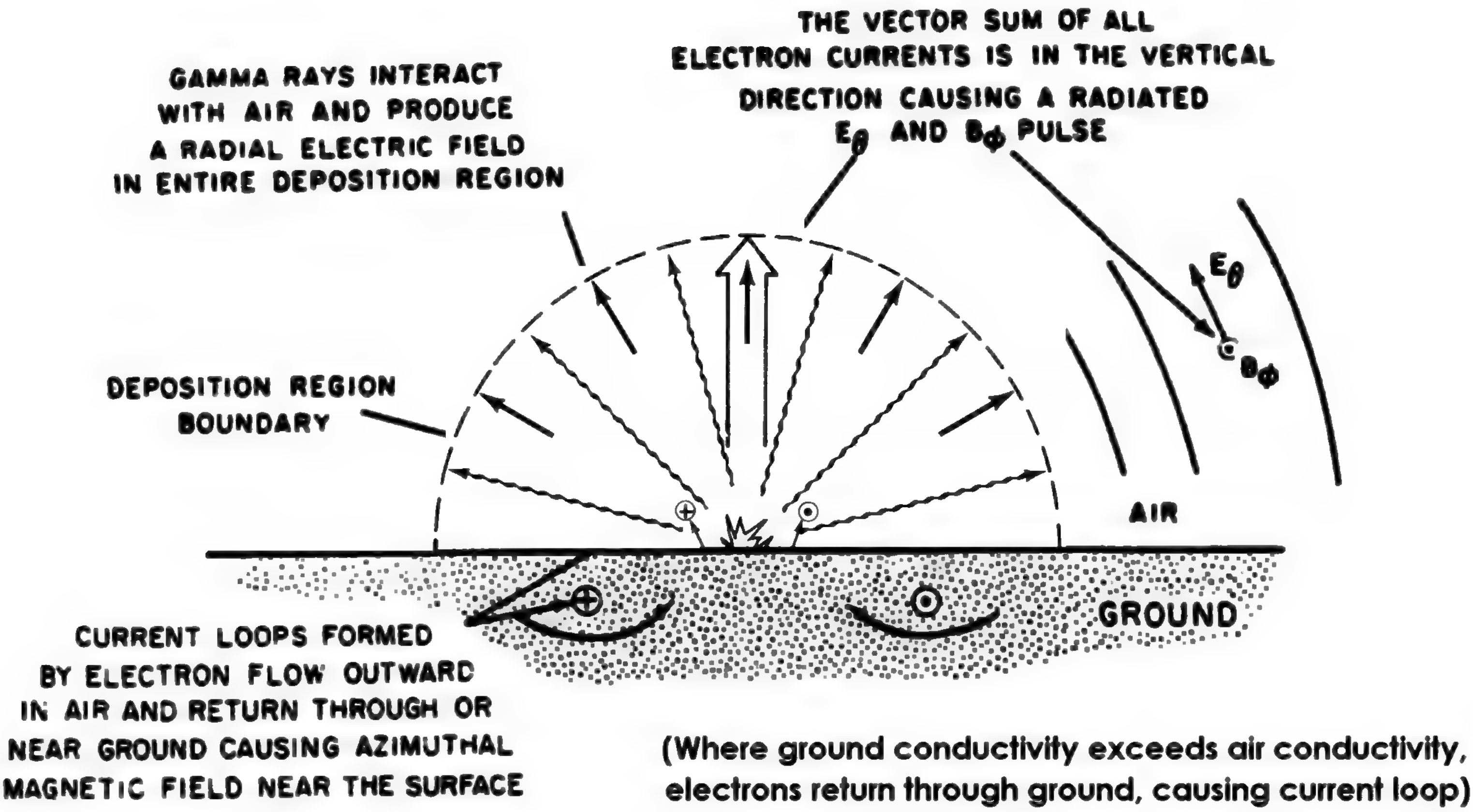


Figure 7-9 Simple Illustration of Surface Burst EMP

The magnitude of the peak value of the radiated electric waveform for a surface burst is a weak function of yield, varying from about 1,300 volts per meter at R_o for a 4.2 TJ (1KT) explosion to about 1,670 volts per meter for a 4.2×10^4 TJ (10 MT) explosion. For most cases, a value of 1,650 volts per meter may be assumed. At ranges along the surface beyond R_o, the peak radiated electric field varies inversely with the distance from the burst. Thus, the magnitude of the peak radiated electric field along the surface may be estimated from the equation

$$E = \frac{R_o}{R} E_o ,$$

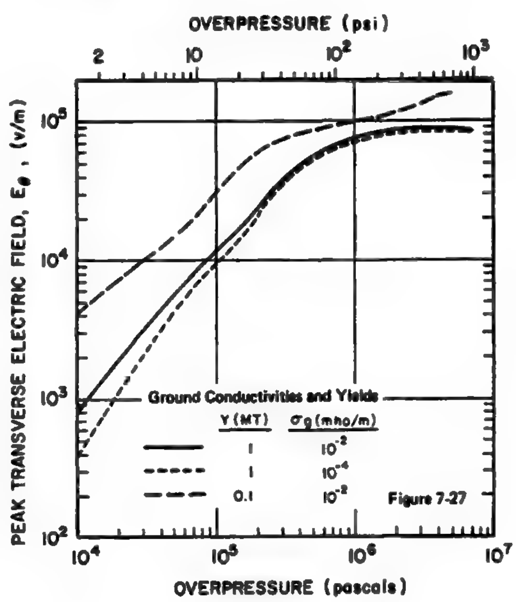
where R_o is the range to the beginning of the radiation region, R is the distance along the surface to the point of interest, E_o is the peak value of the radiated field at R_o (assumed to be about 1,650 volts per meter), and E is peak value of the radiated field at R.

10 kilometers from a 1 MT surface burst

$$E = \left(\frac{7.2}{10}\right)(1{,}650) \approx 1{,}200 \text{ v/m.}$$

10 kilometers from a 100 KT surface burst

$$E = \left(\frac{5.8}{10}\right)(1{,}650) \approx 950 \text{ v/m.}$$



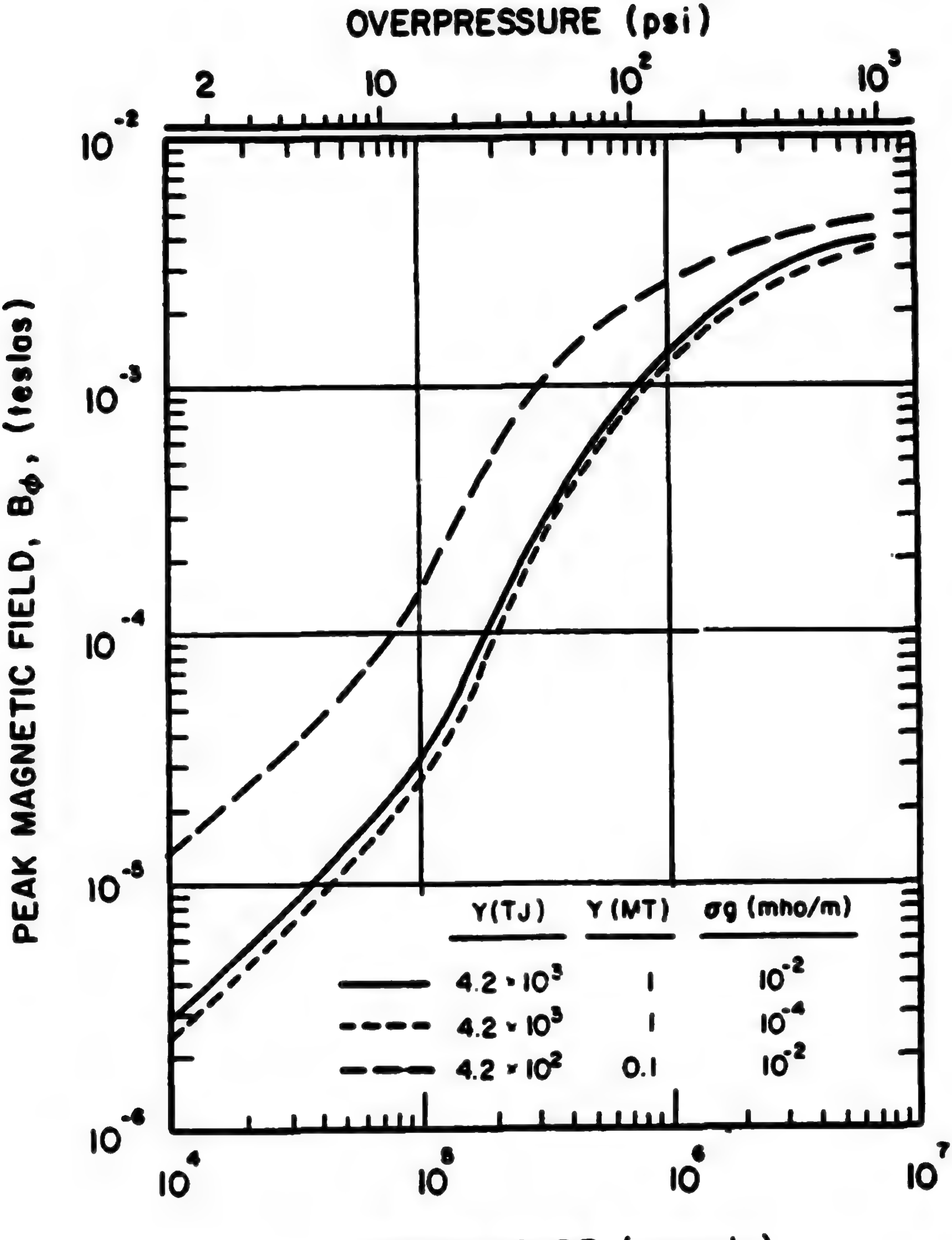


Figure 7-25 Peak Magnetic Field B_ϕ Versus Overpressure for Varying Ground Conductivities and Yields

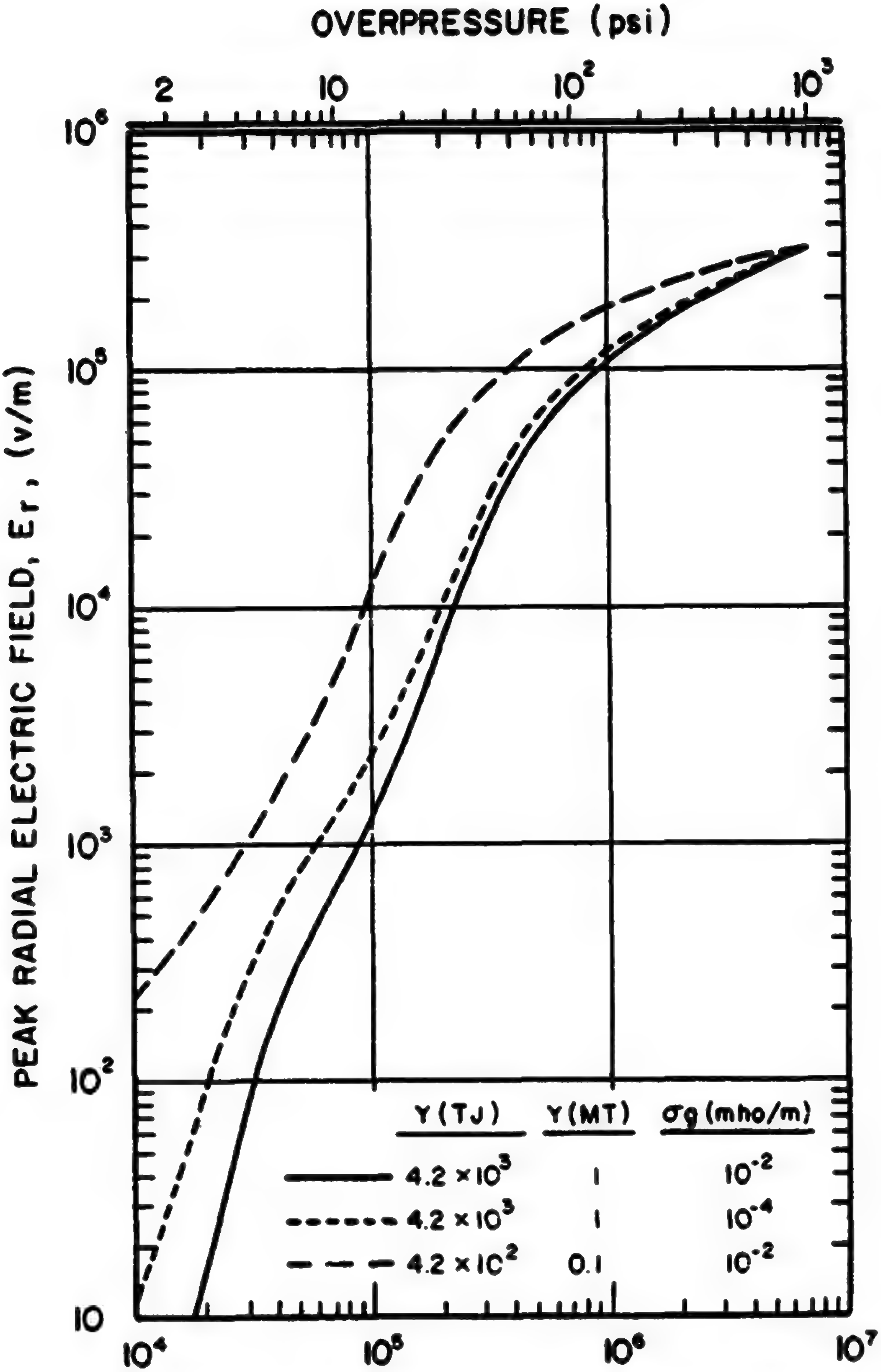


Figure 7-26 Peak Radial Electric Field E_r Versus Overpressure for Varying Ground Conductivities and Yields

SECTION VIII

[redacted] ELECTROMAGNETIC PULSE (EMP) DAMAGE MECHANISMS [redacted]

[redacted] As described in Chapter 7, the nuclear electromagnetic pulse (EMP) is part of a complex environment produced by a nuclear environment. The EMP contains only a very small part of the total energy produced by a nuclear explosion; however, under the proper circumstances, EMP is capable of causing severe disruption and sometimes damage to electrical and electronic systems at distances where all other effects are absent.

[redacted] As with the EMP generation described in Chapter 7, the complexity of the calculation of EMP damage mechanisms requires that heavy reliance be placed on computer code calculations for specific problems, and even these calculations must be supplemented by testing in most cases. Consequently, the information presented herein is largely qualitative and will only serve as an introduction to the subject. More complete treatments of EMP damage mechanisms may be found in the "DNA EMP (Electromagnetic Pulse) Handbook" (see bibliography).

[redacted] Figure 7-18, Chapter 7, provides a matrix that provides some indication of whether EMP constitutes a threat in a given situation relative to the hardness of a system to blast overpressure. This section provides a brief description of EMP energy coupling, component damage, EMP hardening, and testing.

[redacted] ENERGY COUPLING [redacted]

9-56 Basic Coupling Modes [redacted]

[redacted] There are three basic modes of coupling the energy contained in an electromagnetic wave into the conductors that make up an electric or electronic system: electric induction, magnetic induction, and resistive coupling.

[redacted] Electric induction arises as the charges in a conductor move under the influence of the tangential component of an impinging electric field. The overall result is that of a voltage source distribution along the conductor. One such point-voltage source is shown in Figure 9-65 for a simple conducting wire, where the current I is produced as a result of the tangential component $E_{i\ tan}$ of the incident electric field $\bar{E}_i$.

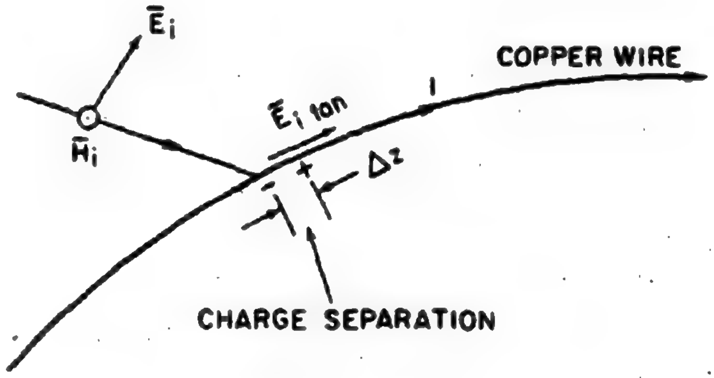


Figure 9-65. [redacted] Electric Induction in a Copper Wire [redacted]

[redacted] Magnetic induction occurs in conductors shaped to form a closed loop when the component of the impinging magnetic field perpendicular to the plane of the loop varies in time, causing charges to flow in the loop. This effect is illustrated in Figure 9-66 for a simple wire loop. Here the magnetic field is shown coming out of the plane of the loop. The loop need not be circular, and magnetic induction may occur with any set of conducting components assembled so as to form a loop.

[redacted] Resistive coupling comes about indirectly as a conductor that is immersed in a conducting medium, such as ionized air or the ground, is influenced by the currents induced in the medium by the other coupling modes. In effect the conductor shares part of the current as an alternate conducting path. This effect is illustrated in Figure 9-67 for the simple case of a

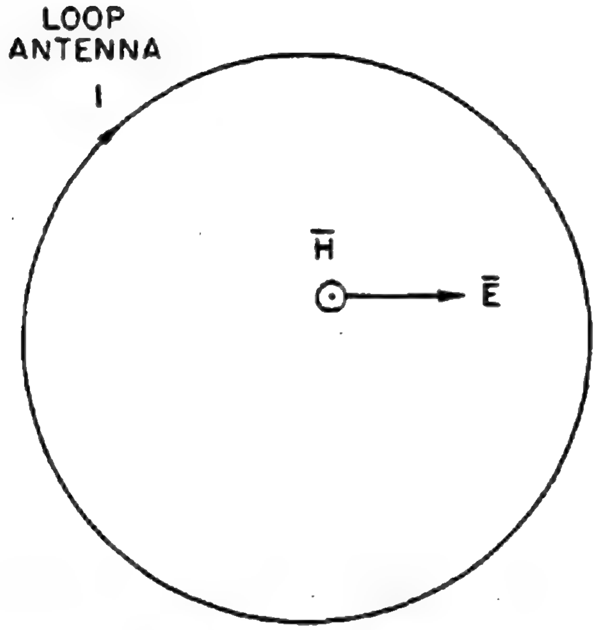


Figure 9-66. [redacted] Magnetic Induction in a Simple Loop [redacted]

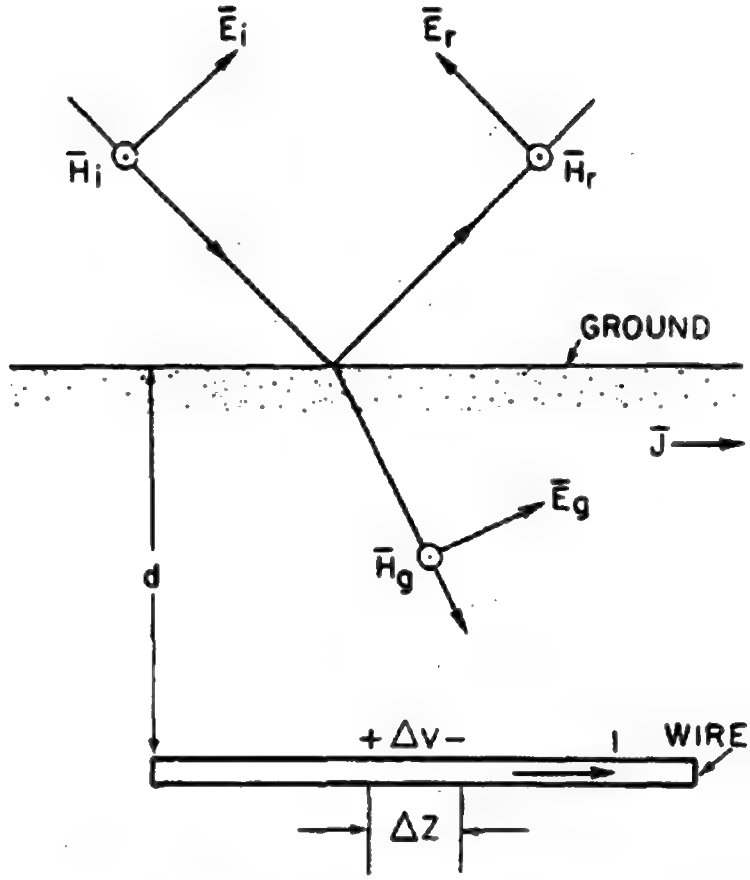


Figure 9-67. [redacted] Resistive Coupling as a Result of Currents in the Ground [redacted]

[redacted] conductor immersed in the ground. The tangential component of the incident electric field $\bar{E}_i$ induces a current density $\bar{J}$ in the ground. A distributed voltage drop appears along the wire as a result of the current flow in the ground, and this incremental voltage causes current flow I in the wire. Current also may be induced in the wire directly by the tangential component of the refracted electric field, shown as $\bar{E}_g$. The reflected EMP, $\bar{E}_r$, $\bar{H}_r$, is also shown in Figure 9-67. The potential importance of these reflected fields is discussed below.

9-57 Resonant Configurations [redacted]

[redacted] The coupling of energy to a conductor is particularly efficient when the maximum dimension of the conductor configuration is about the same size as the wavelength of the radiation. In this event the voltages that are induced along the conductor at various points are all approximately in phase, so the total voltage induced on the conductor is a maximum. The conductor is said to be resonant, or to behave as an antenna, for frequencies corresponding to near this wavelength. Since EMP has a broad spectrum of frequencies (see Chapter 7), only a portion of this spectrum will couple most efficiently into a specific conductor configuration. Thus, a particular system of interest must be examined with regard to its overall configuration as well as its component configuration. Eash aspect will have characteristic dimensions that determine what part of the pulse (strength and frequencies) constitutes the principal threat.

[redacted] Gross system features that are not nor[redacted] considered antennas, such as structural features, beams, girders, buried cable, overhead conduit or ducting, wings, fuselage, missile skins, and any wall apertures, must be considered to be potential collectors and conductors of energy into the system. In particular, radiation that

Table 9-27. Minimum Observed Joule Energy to Cause Burnout

Type	Minimum Joule Energy	Material	Other Data
2N36	4.0×10^{-2}	Ge	PNP Audio Transistor
2N327A	1.6×10^{-2}	Si	PNP Audio Transistor
2N1041	2.0×10^{-2}	Ge	PNP Audio Transistor
2N1308	5.0×10^{-5}	Ge	NPN Switching Transistors
2N706	6.0×10^{-5}	Si	NPN Switching Transistors
2N594	6.0×10^{-3}	Ge	NPN Switching Transistors
2N398	8.0×10^{-4}	Ge	PNP Switching Transistors
2N240	1.0×10^{-2}	Ge	PNP Switching Transistors
MC715	8.0×10^{-5}	Si	Data Input Gate Integrated Circuit
2N4220	1.0×10^{-5}	Si	RF General Purpose FET
2N4224	3.0×10^{-5}	Si	VHF Amp and Mixer FET
1N3659	8.0×10^{-3}	Si	Automotive Rectifier Diode
1N277	2.0×10^{-5}	Ge	High Speed Switching Diode
1N3720	5.0×10^{-4}		Tunnel Diode
1N238	1.0×10^{-7}	Si	Microwave Diode
2N3528	3.0×10^{-3}	Si	Silicon Controlled Rectifier
67D-5010	1.0×10^{-4}		G.E. Varistar (30-joule Rating)
6AF4	1.0×10^{0}		UHF Oscillator Vacuum Tube
66N8	2.0×10^{0}		General Purpose Triode Vacuum Tube

Table 9-28. [redacted] Minimum Joule Energy to Cause Permanent Degradation Indicated [redacted]

Designation	Minimum Joule Energy	Malfunction	Other Data
Relay	2×10^{-3}	Welded Contact	Potter-Brumfield (539) low-current relay
Relay	1×10^{-1}	Welded Contact	Sigma (IIF) one-ampere relay
Microammeter	3×10^{-3}	Slammed Meter	Simpson Microammeter (Model 1212C)
Explosive Bolt	6×10^{-4}	Ignition	EBW 8 amp for 10 μsec detonator, MK1
Squib	2×10^{-5}	Ignition	Electric Squib, N8 3.5 watts for 5 μsec detonator
Fuel Vapors	3×10^{-3}	Ignition	Propane-air mixture 1.75 mm ignition gap

[redacted] second pulses. Capacitors are also fairly hard components. The approximate energies required for degradation of several common components are shown in Table 9-28.

[redacted] The minimum energy necessary for operational upset is a factor of 10 to 100 less than that which is required to damage the most sensitive semiconductor component. Table 9-29 shows the levels required to cause operational upset to some common components to illustrate this factor.

[redacted] A gross comparison of the energy required to damage several classes of electrical equipment is provided in Figure 9-69.

[redacted] The large range of damage levels emphasizes the fact that it is important to consider EMP damage criteria early during the design stage of any piece of equipment that might be susceptible. It is also important to realize that energy collected in one part of a system may be transmitted to other parts of the system as a result of the currents that are induced. Thus, it is not necessary that the EMP couple directly to a sensitive component; energy coupled to various parts of a system may ultimately reach a particular component in sufficient quantity to cause malfunction. With the current state of the art in EMP vulnerability evaluation, the design and hardening of complicated systems requires the joint efforts of systems engineers and professional EMP effects personnel.

[redacted] EMP HARDENING [redacted]

9-60 System Analysis [redacted]

[redacted] A general approach to the examination

Table 9-29. [redacted] Minimum Joule Energy to Cause Circuit Upset or Interference [redacted]

Designation	Minimum Joule Energy	Malfunction	Other Data
Logic Card	3×10^{-9}	Circuit Upset	Typical logic transistor inverter gate
Logic Card	1×10^{-9}	Circuit Upset	Typical flip-flop transistor assembly
Integrated Circuit	4×10^{-10}	Circuit Upset	Sylvania J-K flip-flop monolithic integrated circuit (SF50)
Memory Core	2×10^{-9}	Core Erasure Via Wiring	Burroughs fast computer core memory (FC2001)
Memory Core	5×10^{-8}	Core Erasure Via Wiring	Burroughs medium speed computer core memory (FC8001)
Memory Core	3×10^{-9}	Core Erasure Via Wiring	RCA medium speed, core memory (269M1)
Memory Core	2×10^{-8}		Minimum observable energy in a typical high-gain subsystem
Amplifier	4×10^{-21}	Interference	Minimum observable energy in a typical high-gain amplifier

[redacted]

of a system with regard to its EMP vulnerability could include the following steps. First information concerning the system components and devices is collected. The information is categorized methodically into physical zones based on the susceptibility and worst case exposure for these items. Using objective criteria, problem areas are identified, analyzed, and tested. Suitable changes are made as necessary to correct deficiencies, and the modified system is examined and tested. The approach may be followed on proposed systems or those already in place, although experience indicates that the cost of retrofitting EMP protection is usually overwhelming.

9-61 Recommended Practices [redacted]

[redacted] Within the scope of this manual it is only possible to mention a few of the practices that may be employed in hardening a system to EMP. The following discussion is intended to convey some impression of the extra effort involved in hardening a system to the EMP rather than to provide a comprehensive treat-

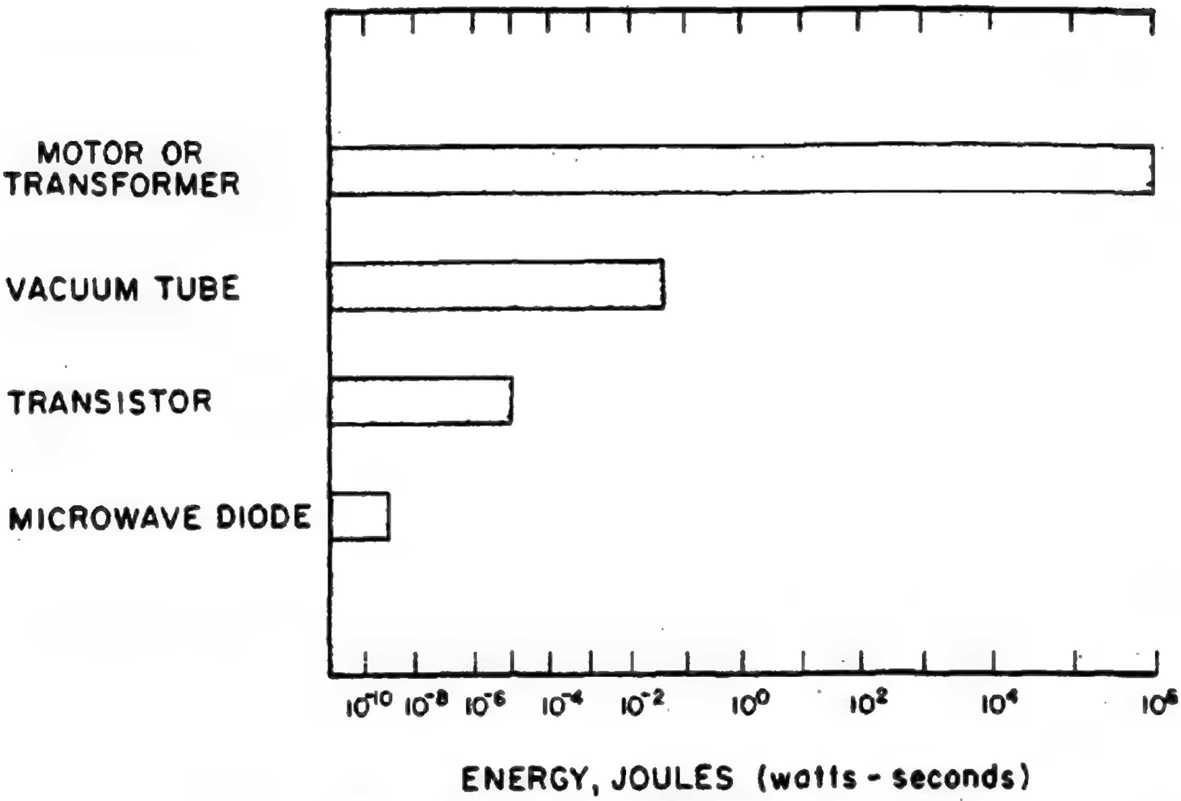


Figure 9-69. [redacted] Energy Required to Damage Various Classes of Equipment [redacted]

ment of what is a highly technical and specialized field.

[redacted] Some general methods for reduction of the EMP environment include geometric arrangement of the equipment, shielding, geographic relocation, and proper grounding.

[redacted] Circuit layout recommendations include the use of common ground points, twisted cable pairs, system and intrasystem wiring in "tree" format (radial spikes) avoiding loop layouts and circuit routes coupling to other circuits, use of conduit or cope trays, and shielded isolated transformers. Avoiding ground return in cable shields is also recommended. Many specific practices carry over from communications and power engineering while many do not. Each must be examined carefully.

[redacted] Good shielding practices include the use of independent zone shields, several thin shields to replace a thick one, continuous shield joints, and keeping sensitive equipment away from shield corners. Avoiding shield apertures, and avoiding the use of the shield as a ground or return conductor is also recommended. The shielding effectiveness of many enclosures frequently is defeated by energy carried by cables or pipes (including water pipes, sewage lines, etc.) into the enclosure.

[redacted] Cabling recommendations include the use of deeply buried intersystem cables (more than 3 feet), shield layer continuity at splices, and good junction box contact. Ordinary braid shielding should be avoided. Cable design represents an extension of shielding and circuit practices from the viewpoint of EMP protection. It is an area where compromises frequently are made in the interests of economy, and thus is an area where professional EMP effects personnel can be

Table 2-9. [redacted] Measured Wave Data from Nuclear Tests [redacted]

NUMBER SERIES SHOT	YIELD	WATER DEPTH AT CHARGE	DEPTH OF BURST	PEAK WAVE* HEIGHT x RANGE	CAVITY RADIUS	$d_w/100(W)^{1/4}$	$HR/2 \times 10^4 \sqrt{W}$
	W (kt) $100(W)^{1/4}$	d_w (ft)	d_b (ft)	HR/2,000 (ft)† min - max	R_c (ft)		min - max
1 HARDTACK UMBRELLA	[redacted]	140	140	[redacted]	[redacted]	[redacted]	[redacted]
2 HARDTACK WAHOO	[redacted]	3,000	500	[redacted]	[redacted]	[redacted]	[redacted]
3 CROSSROADS BAKER	23.5 220	180	90	36 - 60	1,000‡	0.82 Shallow	0.74 - 1.24
4 WIGWAM	32 238	15,000	2,000	118	490†	63 Very Deep	2.08
5 REDWING FLATHEAD	[redacted]	120	0	[redacted]	[redacted]	[redacted]	[redacted]
6 REDWING DAKOTA	[redacted]	140	0	[redacted]	[redacted]	[redacted]	[redacted]
7 REDWING NAVAHO	[redacted]	230	0	[redacted]	[redacted]	[redacted]	[redacted]
8 CASTLE UNION	7,000 916	145	7	232 - 312	1,000†	0.16 Shallow	0.16 - 0.28
9 CASTLE YANKEE	13,500 1,080	220	7	426 - 438	1,000†	0.20 Shallow	0.37 - 0.38

*H is twice the measured height of the peak crest except for shots 8 and 9 where H is the measured height of the first crest from the following trough. H is corrected for uniform water depth = d_b by Green's law.
†Value deduced from measured surface wave train (Kaplan and Wallace, see bibliography) is a lower limit considerably smaller than actual values, which are unknown.
‡Measured values of the column radius (Young, DASA 1240-1(9)), see bibliography.

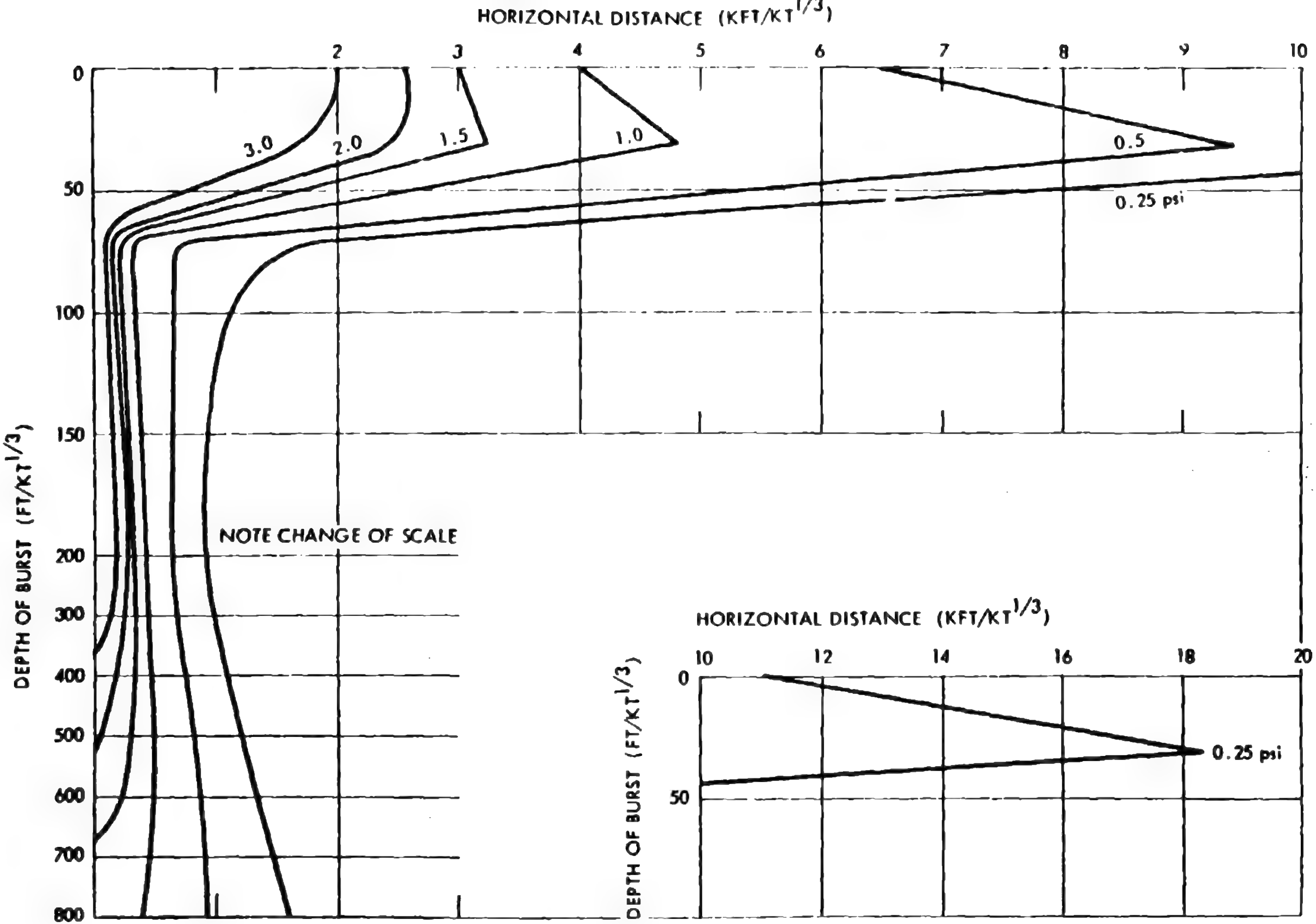


Figure 2-121 Peak Air Blast Overpressure Along the Water Surface from Underwater Nuclear Explosions

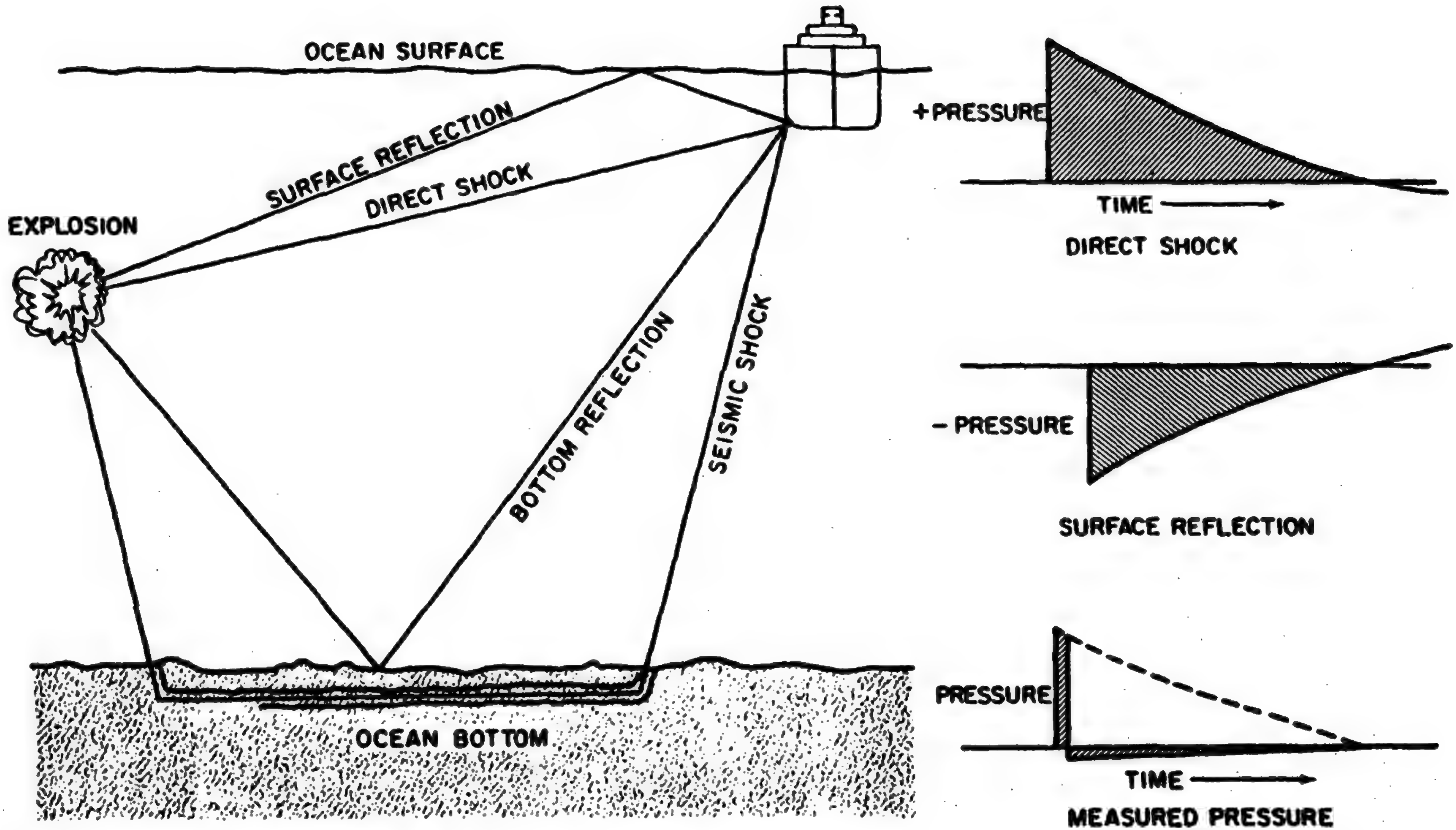


Figure 9-4. [redacted] Direct and Reflected Shock Waves from an Underwater Burst [redacted]

July 1973

AD763750

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DNA 3054F

URS 7049-10, Rev. 1

FOREST BLOWDOWN FROM NUCLEAR AIRBLAST

by

Phillip J. Morris

for

Headquarters
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

Contract No. DNA-001-72-C-0021

A sensitivity analysis is performed on a computer model of tree response to airblast loading. This effort was undertaken, with success, to reduce the number of input parameters required by the model to those available to the field commander. Based on the results of this analysis, a new prediction technique was developed which determines the extent of tree blowdown and the resultant effects on troop and vehicle movement. The technique was developed for inclusion in DNA Effects Manual Number 1.

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Fig. 15-35 in DNA-EM-1 (1972)

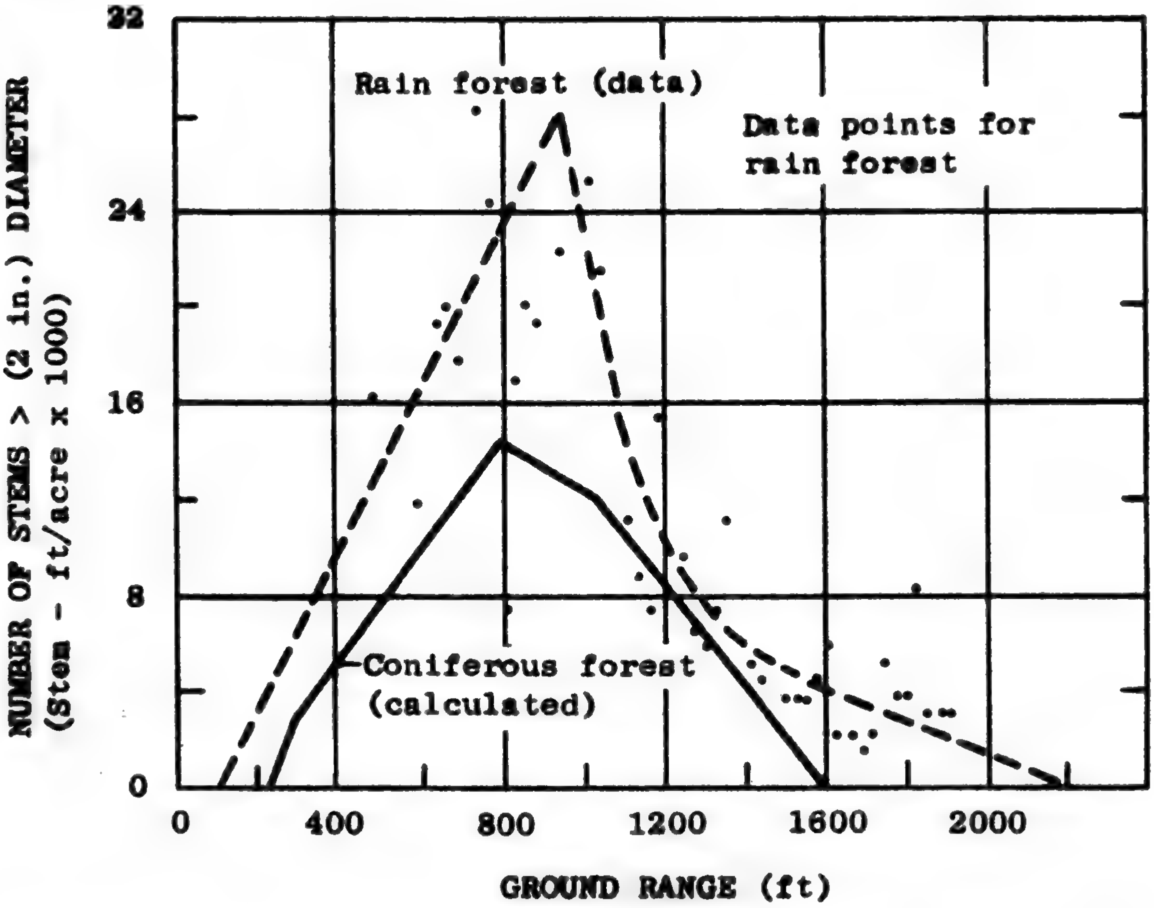

Fig. 15-8. Stem-ft per Acre Comparison Between a Rain Forest and a Coniferous Forest, 1 KT

Fig. 15-36 in DNA-EM-1 (1972)

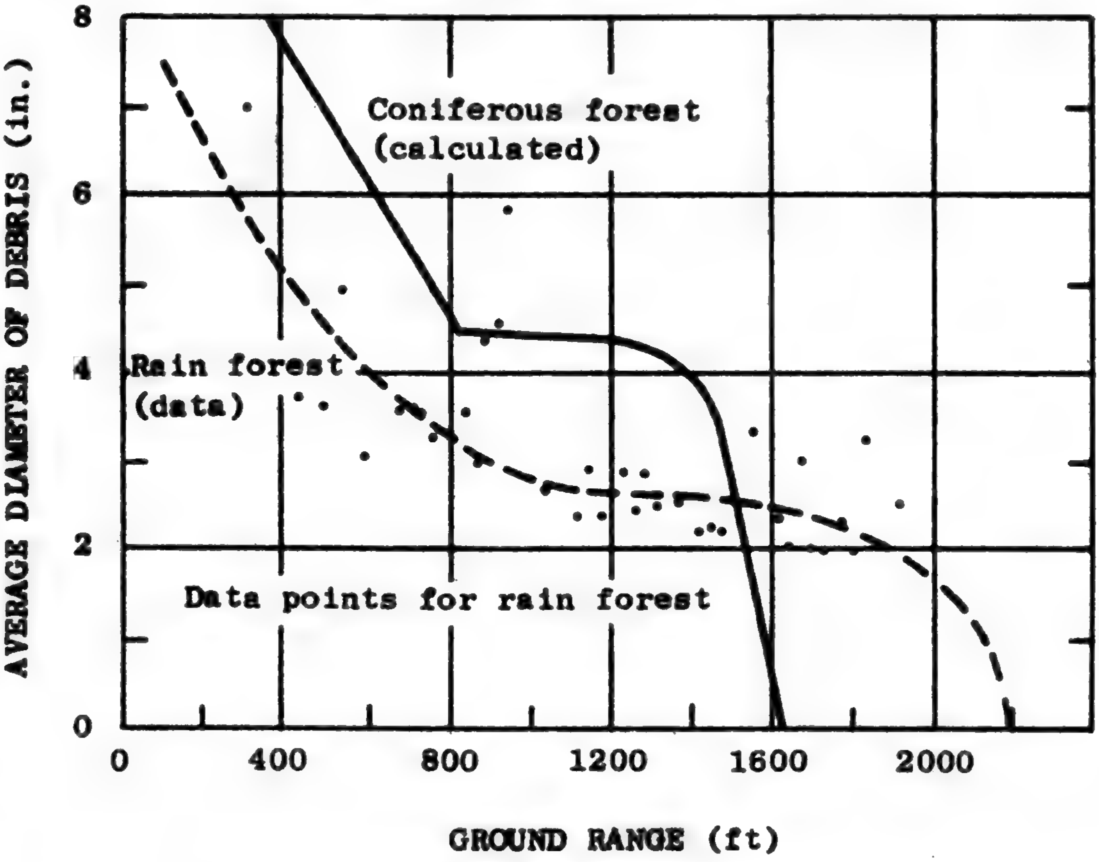

Fig. 15-9. Average Diameter of Stems Down, Comparison Between a Rain Forest and a Coniferous Forest, 1 KT

Fig. 15-46 in DNA-EM-1 (1972)

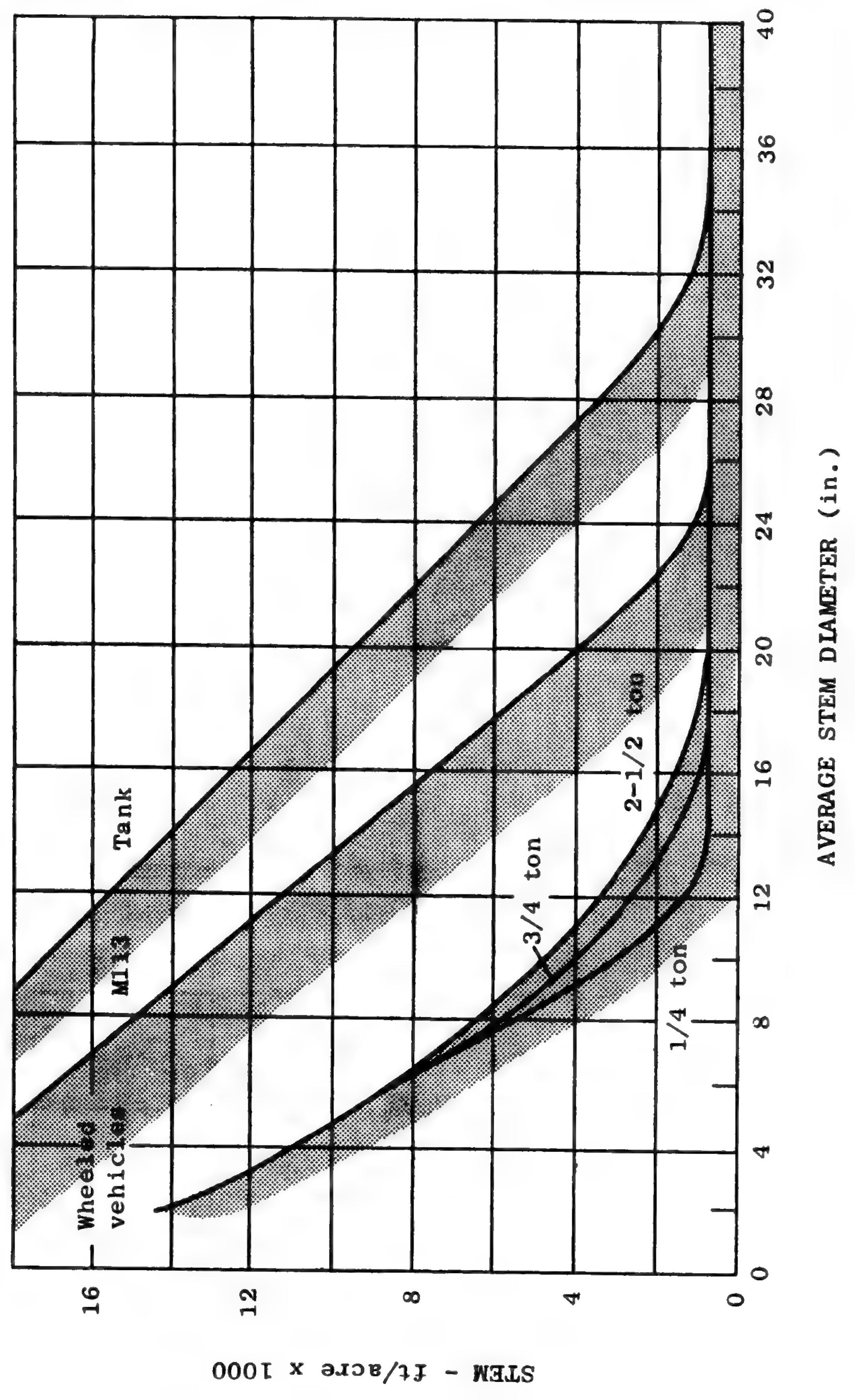

Fig. 15-10. Debris Characteristics Preventing Circumferential Movement of Vehicles

Fig. 15-37 in DNA-EM-1 (1972)

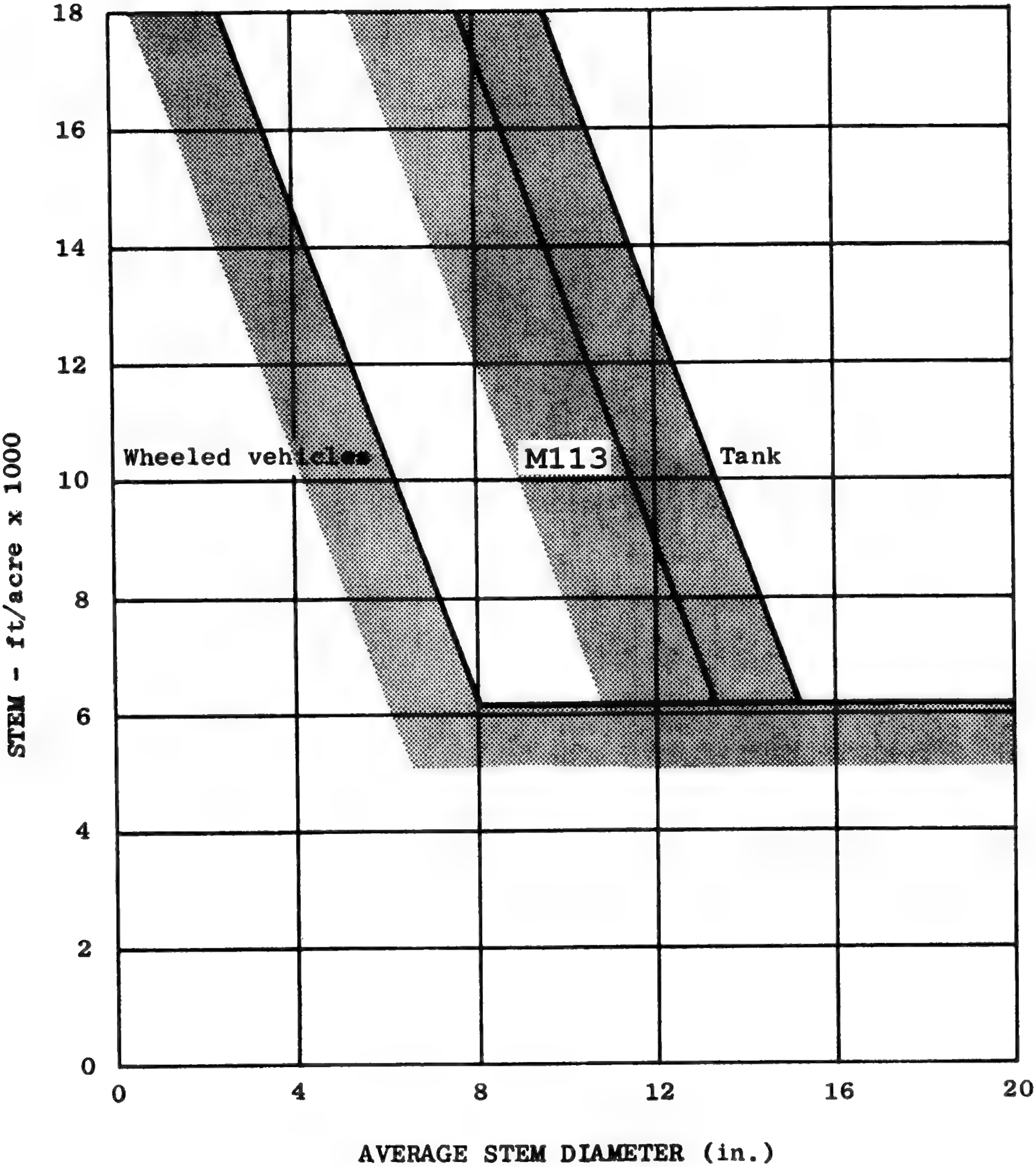

Fig. 15-11. Debris Characteristics Preventing Radial Movement of Vehicles

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[redacted]

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Classification (~~Confidential~~) changed to Memo, Ch. Security Div. 8-20-57
By Authority of
By G. Hamos/ca Date OCT 24 1957

HANDBOOK

on

CAPABILITIES

of

ATOMIC WEAPONS

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[redacted]

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10.3 Damage Criteria

10.31 The tables presented in this section show various target items, their criteria for different degrees of damage and pertinent remarks. The items are listed in alphabetical order for each type of military operation. An attempt is made to give the source of the data by use of numbers to the right of the damage criteria. The key of this numbering system is indicated below:

a. Full-scale test data (including Hiroshima and Nagasaki . .(1)

b. Estimates made from scale experiments . . . . (2)

c. Theoretical analysis . . . .(3)

d. Consensus of qualified persons . . . .(4)

10.32 For those items not included in Table VIII, select the listed item most similar in those characteristics discussed previously as being the important factors in determining the extent of damage to be expected. Perhaps the most important item to be remembered when estimating effects on personnel is the amount of cover actually involved. This cover depends on several items; however, one factor is all important, namely, the degree of forewarning of an impending atomic attack. It is obvious that only a few seconds warning is necessary under most conditions in order to take fairly effective cover. The large number of casualties in Japan resulted for the most part from the lack of warning.

TABLE VIII
PART I. LAND OPERATIONS

ITEM	DAMAGE	AIR SHOCK PSI	GROUND SHOCK ER	THERMAL ENERGY cal/cm^2	REMARKS
Artillery Field (75mm or greater)	Severe	40 (1)	—	—	S: Damage to Gun and Cradle
	Moderate	30 (1)	—	—	M: Damage to Recoil and Carriage
	Light	5 (1)	—	15 (1)	L: Damage to Gun Sights, Paint Scorched
Artillery Field (Less than 75mm)	Severe	25 (1)	—	—	S: Damage to Gun and Cradle
	Moderate	15 (1)	—	—	M: Damage to Recoil and Loading Mechanism
	Light	5 (1)	—	15 (1)	L: Damage to Sights, Paint Scorched
Artillery (AA)	Severe	30 (1)	—	—	S: Damage to Gun and Cradle
	Moderate	20 (1)	—	—	M: Damage to Recoil and Carriage
	Light:	5 (1)	—	15 (1)	L: Damage to Electronic Equipment, Paint scorched
Ammunition in Field Dumps	Severe	10 (1)	—	20 (1)	S: Damage due to Ammo being thrown about and possible fires
	Moderate	3 (1)	—	15 (1)	M: Damage due to displacement, secondary effects and heat
	Light	2 (1)	—	10 (1)	L: Small portion damaged due to secondary effects and heat
Bridges (side on blast)	Severe	20	30 (4)	—	S: Bridge collapses. End on blast requires 60 psi
	Moderate	15	25 (4)	—	M: Bridge Displaced. End on blast requires 45 psi
	Light	—	—	—	

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TABLE VIII
PART II
STRUCTURES

ITEM	DAMAGE	AIR SHOCK PSI	GROUND SHOCK ER	THERMAL ENERGY cal/cm^2	REMARKS
Brick Walls (12-18 inch)	Severe	12 (1)	15 (4)	——	S: Collapse
	Moderate	8 (1)	10 (4)	——	M: Partial collapse & cracking
	Light	3 (1)	6 (4)	——	L: Cracking
Homes Brick	Severe	6 (1)	15 (4)	——	S: Collapse
	Moderate	4 (1)	10 (4)	——	M: Distortion and Cracks
	Light	3 (1)	6(4)	——	L: Plaster & window damage
Homes Wooden Frame	Severe	5 (1)	25 (4)	20 (1)	S: Collapse, Burns
	Moderate	3 (1)	15 (4)	12 (1)	M: Distortion & cracks, may burn
	Light	2 (1)	8 (4)	8 (1)	L: Plaster & window damage, scorched
Multistory Brick Bldg.	Severe	6 (1)	15 (4)	——	S: Collapse
	Moderate	4 (1)	10 (4)	——	M: Structural Damage
	Light	3 (1)	6 (4)	——	L: Plaster & window damage
Oil Tank Farms	Severe	10 (2-4)	——	——	S: Tank collapse. This based on Texas explosion. Fires may break out & destroy entire field.
	Moderate	——	——	——	
	Light	——	——	——	
Reinforced Concrete Bldgs.	Severe	25 (1)	30 (4)	——	S: Collapse
	Moderate	10 (1)	20 (4)	——	M: Structural damage
	Light	3 (1)	15 (4)	——	L: Plaster & window damage
Steel, heavy frame Bldgs.	Severe	18 (1)	20 (4)	——	S: Mass distortion
	Moderate	12 (1)	10 (4)	——	M: Structural Damage
	Light	3 (1)	8 (4)	——	L: Plaster & window damage
Steel, light frame Bldgs.	Severe	10 (1)	15 (4)	——	S: Mass distortion
	Moderate	5 (1)	10 (4)	——	M: Structural Damage
	Light	3 (1)	6 (4)	——	L: Plaster & window damage

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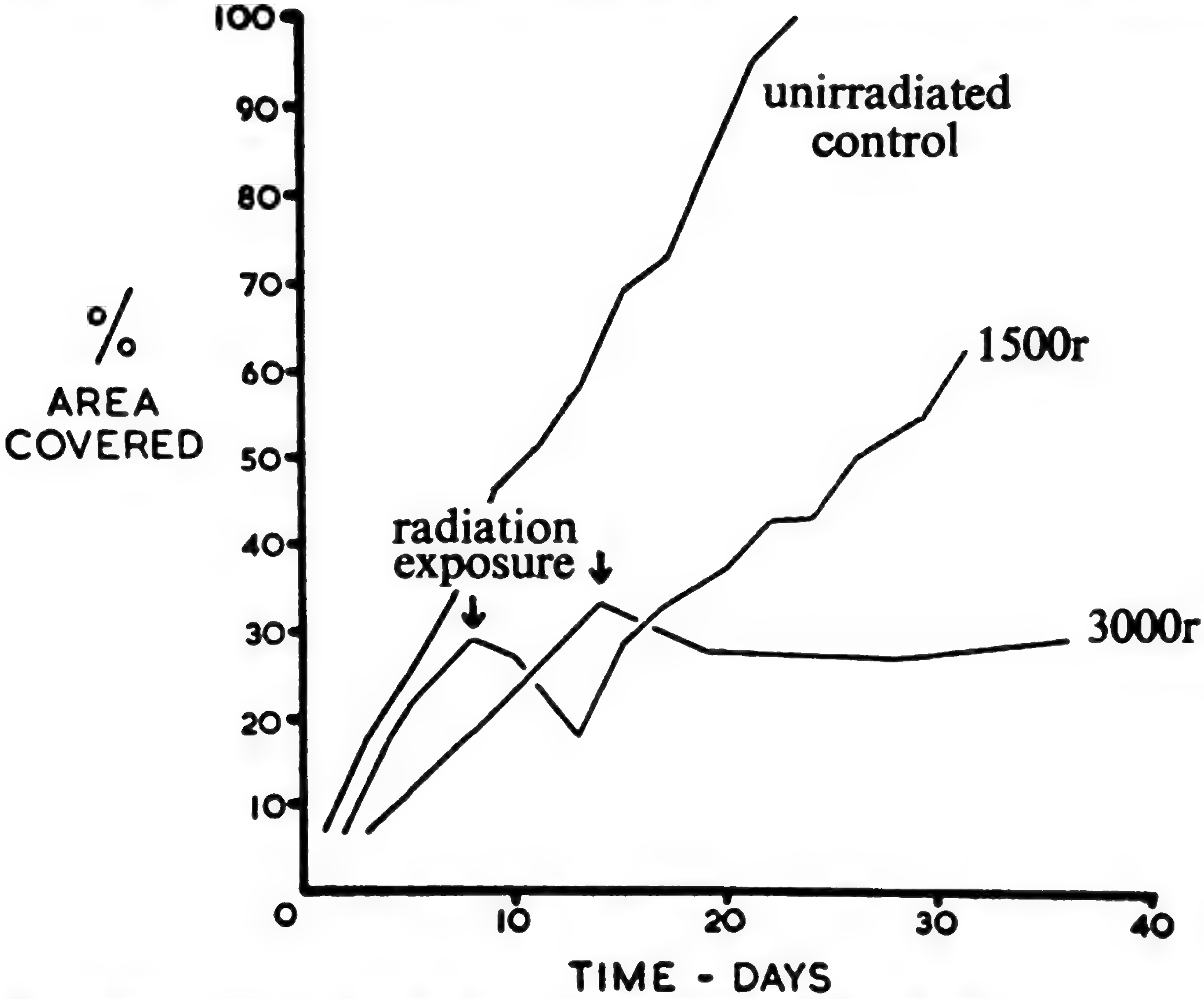
TABLE VIII
PART III

SEA OPERATIONS

ITEM	DAMAGE	AIR SHOCK PSI	WATER SHOCK *Energy Flux, see Fig. 6.74	WATER SHOCK Bikini "B" Distance (ft)	REMARKS
Aircraft Carriers	Severe Moderate Light	30 (1) 20 (1) 5 (1)	300(4) 200(4) 100(4)	2700(1) 3000(1) 4500(1)	S: Complete destruction or sunk M: Immobilized. Failure of primary departments such as elevators. Air shock distorts flight deck. L: Scorching & damage to light and electronic equipment.
Battleships	Severe Moderate Light	45 (1) 25 (1) 5 (1)	300(4) 200(4) 100(4)	2700(1) 3000(1) 4500(1)	S: Complete destruction or sunk M: Immobilized. Failure of primary departments. L: Scorching & damage to light and electronic equipment.
Cruiser (Heavy)	Severe Moderate Light	40 (1) 20 (1) 5 (1)	300(4) 200(4) 100(4)	2700(1) 3000(1) 4500(1)	S: Complete destruction or sunk M: Immobilized. Failure of primary departments L: Scorching & damage to light and electronic equipment.
Cruiser (light)	Severe Moderate Light	30 (1) 20 (1) 5 (1)	300(4) 200(4) 100(4)	2700(1) 3000(1) 4500(1)	S: Complete destruction or sunk M: Immobilized. Failure of primary departments. L: Scorching & damage to light and electronic equipment.
Destroyers	Severe Moderate Light	25 (1) 15 (1) 5 (1)	300(4) 200(4) 100(4)	2700(1) 3000(1) 4500(1)	S: Complete destruction or sunk M: Immobilized. Failure of primary departments. L: Scorching & damage to light and electronic equipment.

Effect of irradiation on rate of growth of granulation tissue



G. H. Blair, H. A. S. van den Brenk, J. B. Walter and D. Slome, "Experimental Study of Effects of Radiation on Wound Healing", in D. Slome, Editor, "Wound Healing: Proceedings of a Symposium 12-13 Nov., 1959, Royal College of Surgeons", Pergamon, 1961, pp. 46-53.

Title : PROCEEDINGS OF A WORKSHOP ON MASS BURNS, 13 - 14 MARCH 1968,

Corporate Author : NATIONAL ACADEMY OF SCIENCES WASHINGTON D C

Personal Author(s) : Walter,Carl W. ; Phillips,Anne W.

Report Date : 1969

Pagination or Media Count : 409

Abstract : This workshop was organized to review the problem of burns, and to marshal data that will permit experts in systems analysis, logistics, mass behavior, and government to apply their skills in planning for the defense of an isolated community that has been largely destroyed by a disastrous fire. Participants have been instructed to focus on the education of a non-medical audience, whose principal interest is civilian defense, and on what to expect from thermal trauma; how to recognize the potential survivors, what measures of self-help can decrease the severity of the illness, how and what to provide in terms of food and water supplies, space and personnel, how to educate the public and train surviving personnel during the weeks or months necessary for the devastated community to reorganize itself and become self-sustaining. (Author)

Descriptors : *BURNS(INJURIES), SYMPOSIA, PATHOLOGY, CASUALTIES, INFECTIOUS DISEASES, CHEMOTHERAPEUTIC AGENTS, TRANSPLANTATION, PROTECTION, THERAPY, RADIATION INJURIES, POPULATION.

Subject Categories : Medicine and Medical Research

MASS BURNS

Proceedings of a Workshop

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PREDICTION OF URBAN CASUALTIES AND THE MEDICAL LOAD FROM A HIGH-YIELD NUCLEAR BURST

L. Wayne Davis

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The Dikewood Corporation
1009 Bradbury Drive, S. E.
University Research Park
Albuquerque, New Mexico 87106

PREDICTION OF URBAN CASUALTIES AND THE MEDICAL LOAD FROM A HIGH-YIELD NUCLEAR BURST

I. INTRODUCTION AND SUMMARY

This work is the result of Dikewood's second iteration at predicting urban casualties due to high-yield nuclear bursts as based on the Japanese nuclear-casualty data from Hiroshima and Nagasaki and on the casualties experienced from the detonation of the ammonium-nitrate fertilizer on board a ship docked at Texas City in 1947. (The first iteration was published in DC-FR-1028, Ref. 1, and DC-FR-1041, Ref. 2.) The Japanese data base has now been more than doubled, and much more information is available on the breakdown of casualties segregated by shielding category. (See DC-FR-1054, Ref. 3.)

Urban casualty predictions are made for nuclear detonations in the yield range from 1 to 50 Mt for scaled burst heights of 0, 300, 585, and 806 feet. (See DC-FR-1060, Ref. 4, to be published.) All casualty curves are given in terms of a reference 12.5-kt surface burst; they must be scaled to the megaton-yield range by the use of scaling curves which are also provided. It is not presently a field manual for easy casualty predictions. Although calculations may be performed by hand, a computer solution is recommended to facilitate the computations for any but the simplest problems. Plans are underway to develop the computer program.

II. CASUALTY CURVES FOR PERSONS IN OR SHIELDED BY STRUCTURES

A. DEVELOPMENT OF "BLAST" MORTALITY CURVES FROM JAPANESE AND TEXAS CITY DATA

A great deal of new information has been gathered concerning the biological effects of the nuclear attacks on Hiroshima and Nagasaki, Japan, during World War II. The data from over 35,000 case histories were collected on magnetic tape, and the results of the analysis were published in DC-FR-1054 (Ref. 3).

The Japanese mortality curves for people in or shielded by structures are plotted as a function of overpressure in Figs. 1 and 2 for Hiroshima and Nagasaki, respectively. These curves are based on a yield for Hiroshima of 12.5 kt burst at a height of 1870 feet (scaled height of 806 feet) and a yield for Nagasaki of 22 kt burst at a height of 1640 feet (scaled height of 585 feet).

The mortality curves from the Texas City disaster of 1947, separated by shielding category, are given as a function of overpressure in Fig. 3. This surface burst* has been estimated to be equivalent to a nuclear yield of 0.67 kt.

The next step was to develop a set of "blast" mortality curves for a reference 12.5-kt surface burst. Of course, the ultimate goal was

---

*Ammonium-nitrate fertilizer exploded within the hold of a ship which was tied up at a pier.

to separate all of the biological damage according to the particular weapons effect which caused it (such as blast, prompt-thermal radiation, or initial-nuclear radiation). Then, each effect could be scaled separately to the higher yield of interest, and the results could be recombined. Joint effects cannot be scaled directly.

For people in or shielded by structures in Japan, the blast and initial-nuclear radiation were the dominant immediate effects. However, when one scales the results to the megaton range, the lethal effects of the initial-nuclear radiation drop out because the blast effects scale to greater ranges. Thus, the blast mortality curves are the set of greatest interest for persons in or shielded by structures. (Similarly, thermal mortality curves are the ones of greatest interest for the outside-unshielded persons.)

By examining a set of theoretical initial-nuclear-radiation mortality curves developed for Hiroshima and Nagasaki and comparing them with the total mortality curves, it could readily be seen that the initial-nuclear radiation played a large role in the deaths of thermally-shielded people located fairly close-in (at the high mortality levels) in the light structures. It is also an important effect even in the concrete structures.

By further comparing the mortality curves for Hiroshima and Nagasaki plotted as a function of overpressure (Figs. 1 and 2), it can

readily be seen that the initial-nuclear radiation was more important or dominant in Hiroshima than in Nagasaki. (It requires more overpressure in Nagasaki to produce the same percent mortality for the equivalent shielding category.) Thus, one would expect the pure blast mortality curves (with no initial-nuclear radiation present) to lie to the right (higher overpressures) of the equivalent Nagasaki curves.

As another boundary condition, the Texas City mortality curves, given in Fig. 3, show the results of blast alone for a lower yield of 0.67 kt. Since a set of blast-mortality reference curves for a 12.5-kt surface burst is the immediate goal, they would appear to lie to the left (lower overpressures) of the equivalent Texas City curves. Of course, this shift is due to the effect of the longer positive-phase duration at the higher yield; it requires less overpressure to produce the same damage at the higher yield. Thus, by scaling the pertinent shielding categories in Texas City up to 12.5 kt and by using the Nagasaki curves as the lower pressure boundaries, the pure blast mortality curves* for the reference 12.5-kt surface burst were developed and are shown in Fig. 4. These blast mortality curves for the reference surface burst are drawn as a smooth function of overpressure since this weapons effects parameter is considered to be the controlling factor in determining the mortality level.

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*It is felt that any deaths in the Japanese data due to the secondary effects of fire have been eliminated by this process.

FIG. 1

TOTAL MORTALITY CURVES FOR HIROSHIMA

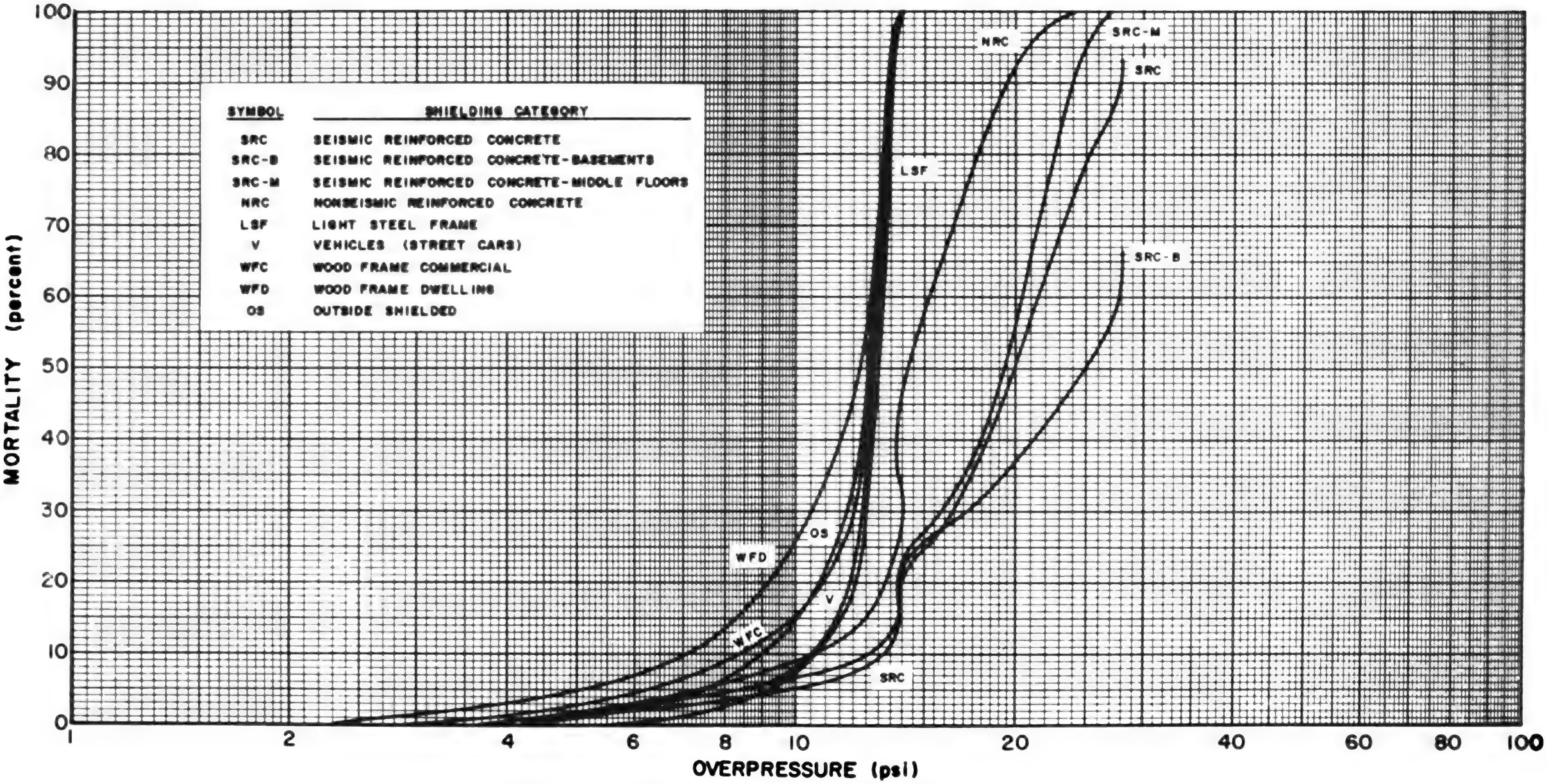


FIG. 2

TOTAL MORTALITY CURVES FOR NAGASAKI

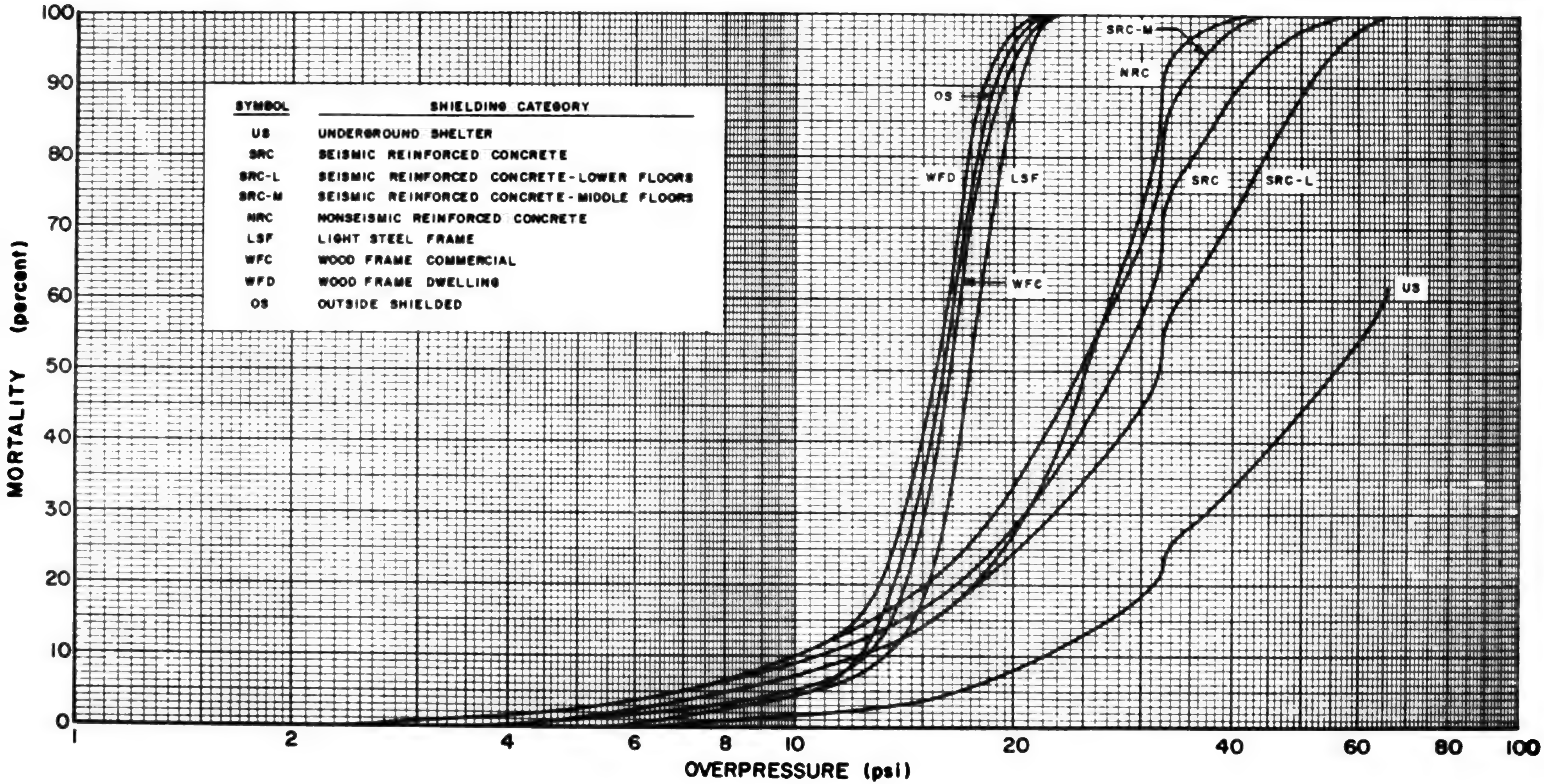


FIG. 3

TOTAL MORTALITY CURVES FOR TEXAS CITY

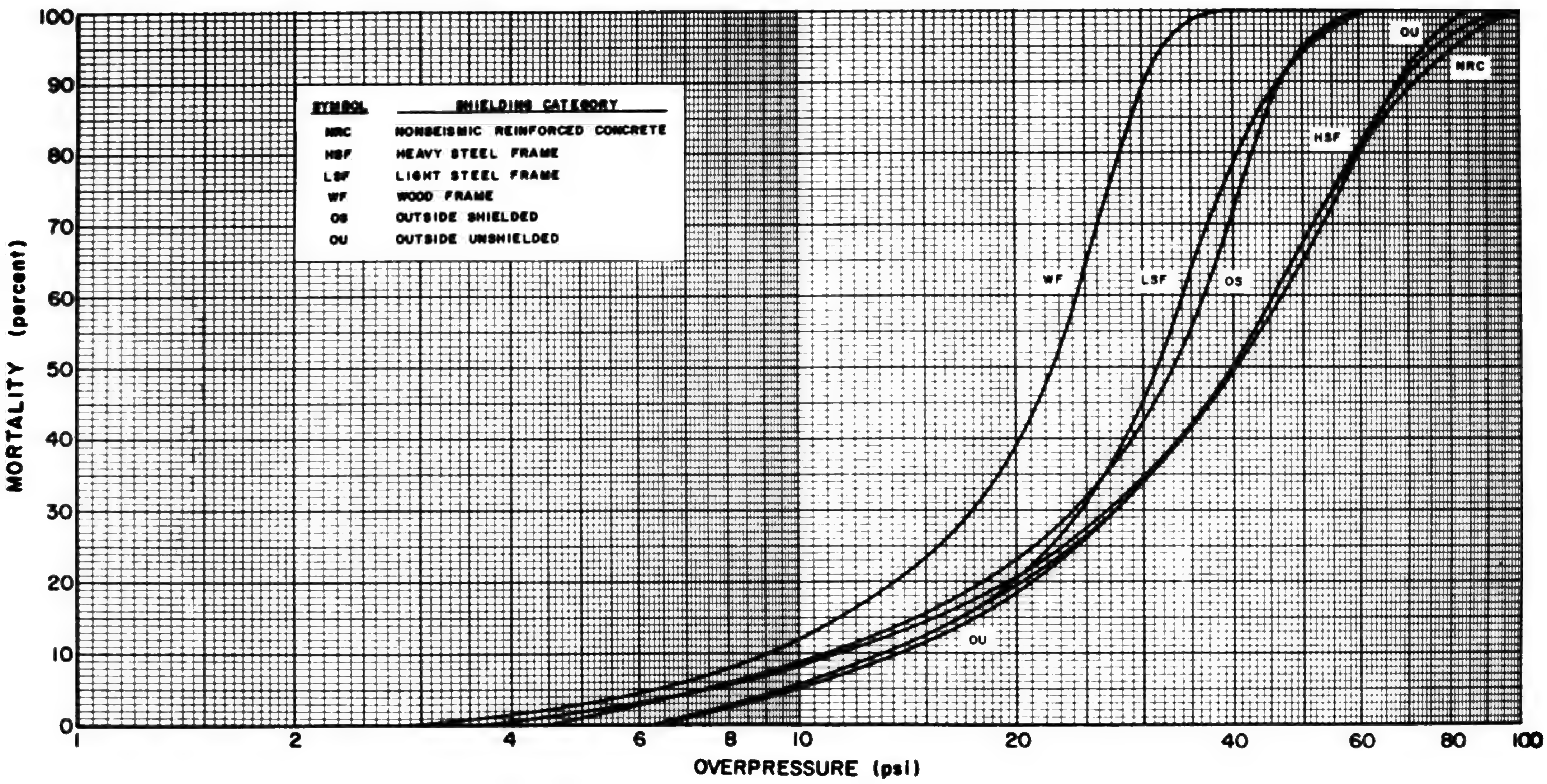


FIG. 4

BLAST MORTALITY CURVES FOR PERSONS IN OR SHIELDED BY STRUCTURES

(12.5-kt SURFACE BURST)

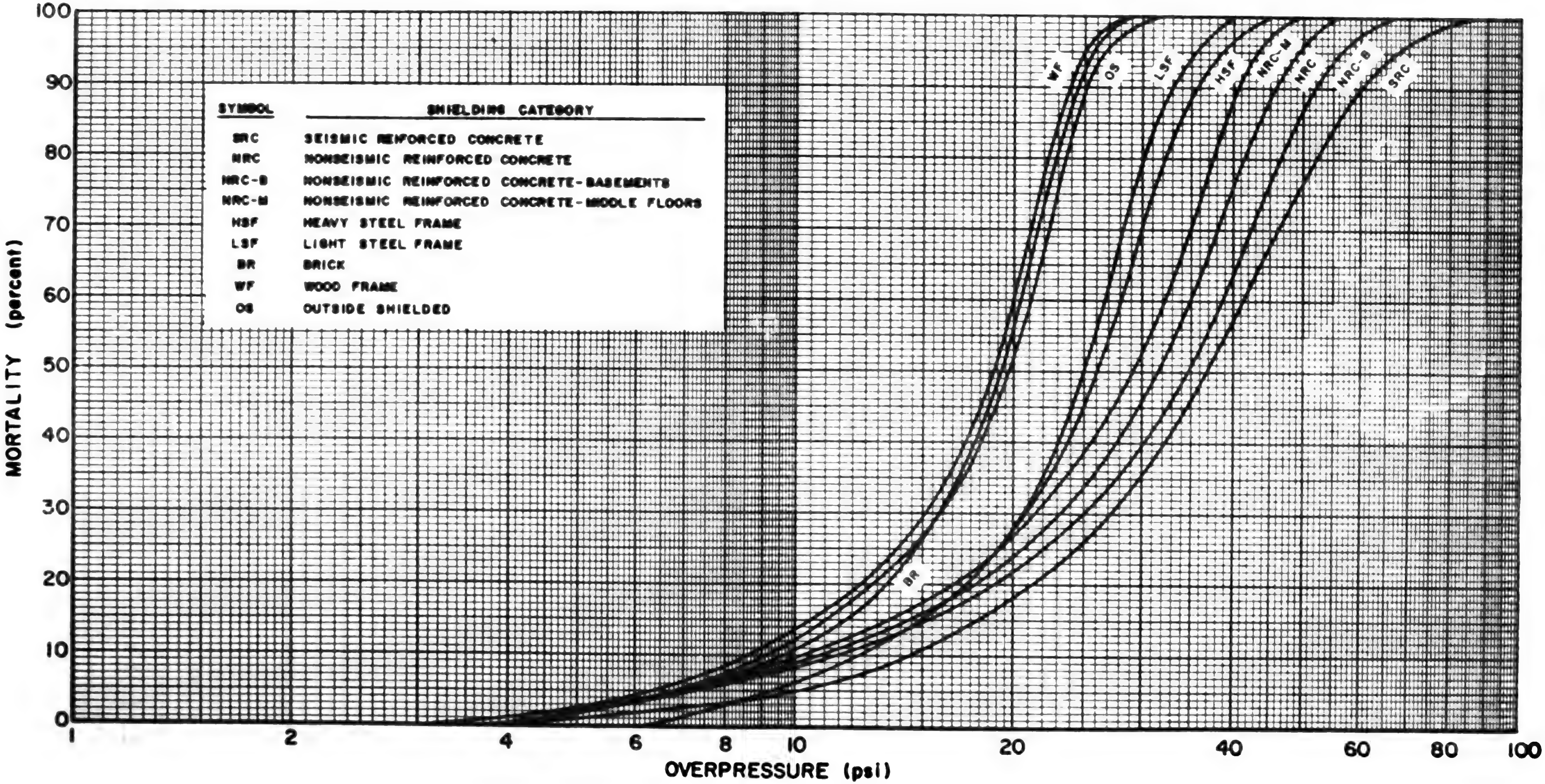


FIG. 7

TOTAL MORTALITY CURVES

FOR NONSEISMIC REINFORCED-CONCRETE BUILDINGS FROM SURFACE BURSTS

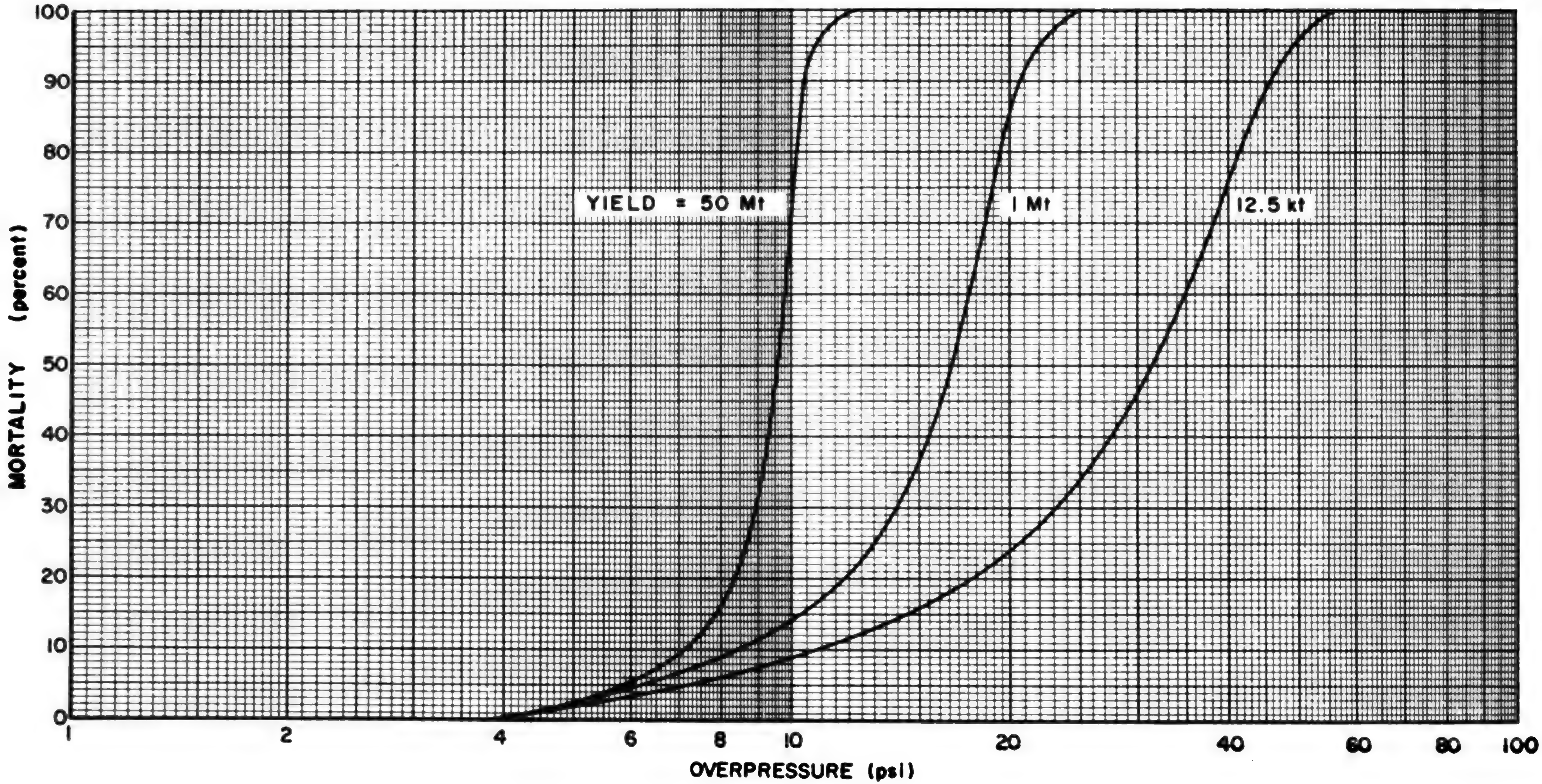
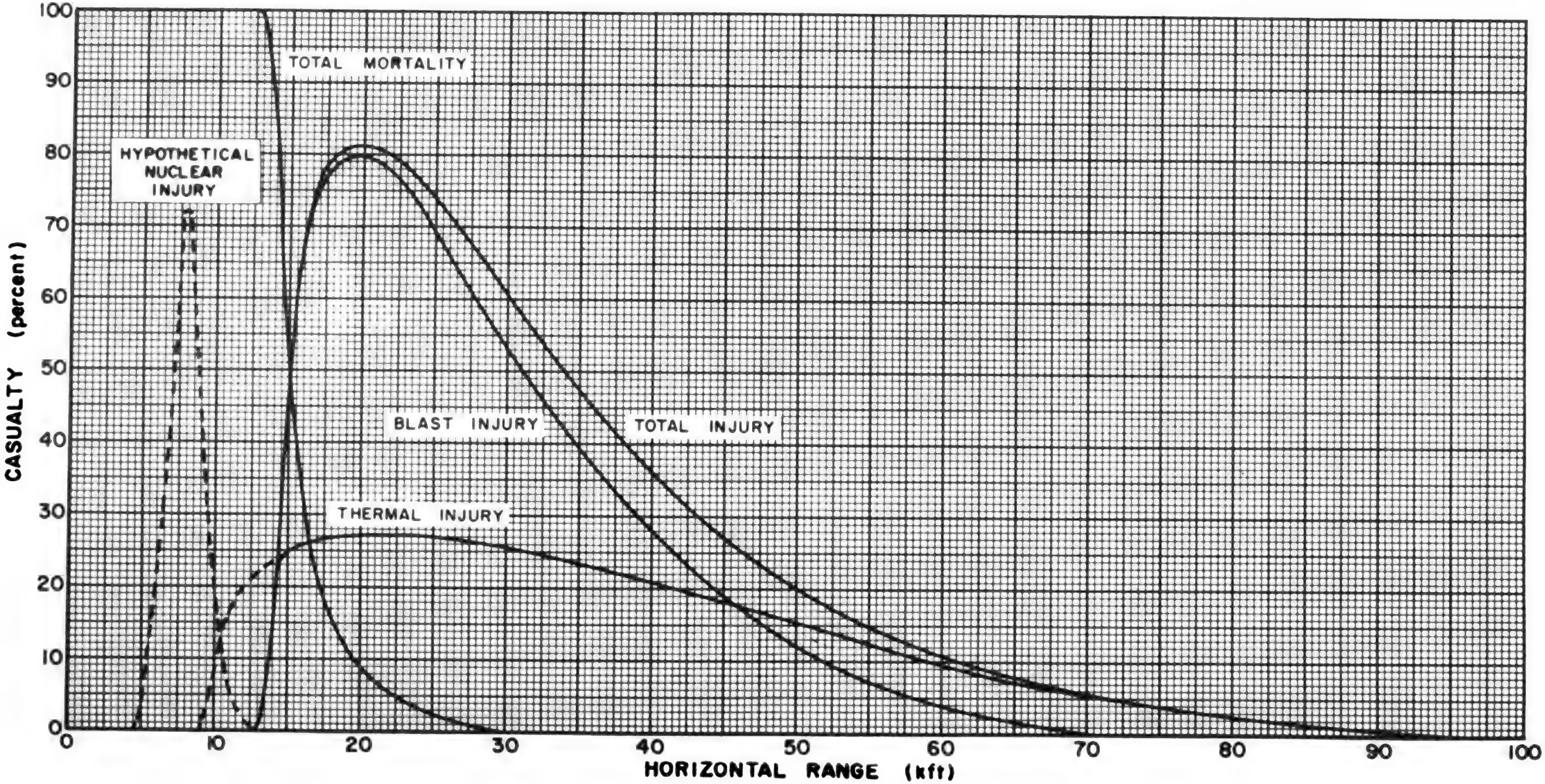


FIG. 10

CASUALTY CURVES VERSUS RANGE FOR NONSEISMIC REINFORCED-CONCRETE BUILDINGS

(5-MT SURFACE BURST)



III. PROMPT-THERMAL CASUALTIES FOR OUTSIDE-UNSHIELDED PERSONS

A. PROMPT-THERMAL MORTALITY CURVE FOR OUTSIDE-UNSHIELDED PERSONS

This curve was much easier to develop than the blast mortality curves (complicated by the effects of the initial-nuclear radiation in Japan) since the prompt-thermal radiation producing flash burns was the dominant effect in Japan as well as for high yields for outside-unshielded persons. Since the predictions of the prompt-thermal exposures in Nagasaki did not correlate well with the burns received, apparently caused by problems in determining the transmissivity, only the new Hiroshima data were used to draw the prompt-thermal mortality curve given in Fig. 19 as a function of the prompt-thermal exposure (cal/cm^2) for the 12.5-kt reference burst. This curve, which is also equivalent to the total mortality curve, can be scaled to higher yields according to the method to be described shortly.

B. PROMPT-THERMAL INJURY CURVE FOR OUTSIDE-UNSHIELDED PERSONS

Before drawing the curves for the <u>surviving</u> injured, all of the data from Hiroshima and Nagasaki were replotted as a function of the appropriate weapons effects levels (cal/cm^2 for prompt-thermal injuries). However, the Hiroshima results were considered to be more reliable than the Nagasaki results for prompt-thermal injuries.

FIG. 19

PROMPT-THERMAL CASUALTY CURVES FROM A 12.5-KT SURFACE BURST FOR OUTSIDE-UNSHIELDED PERSONS

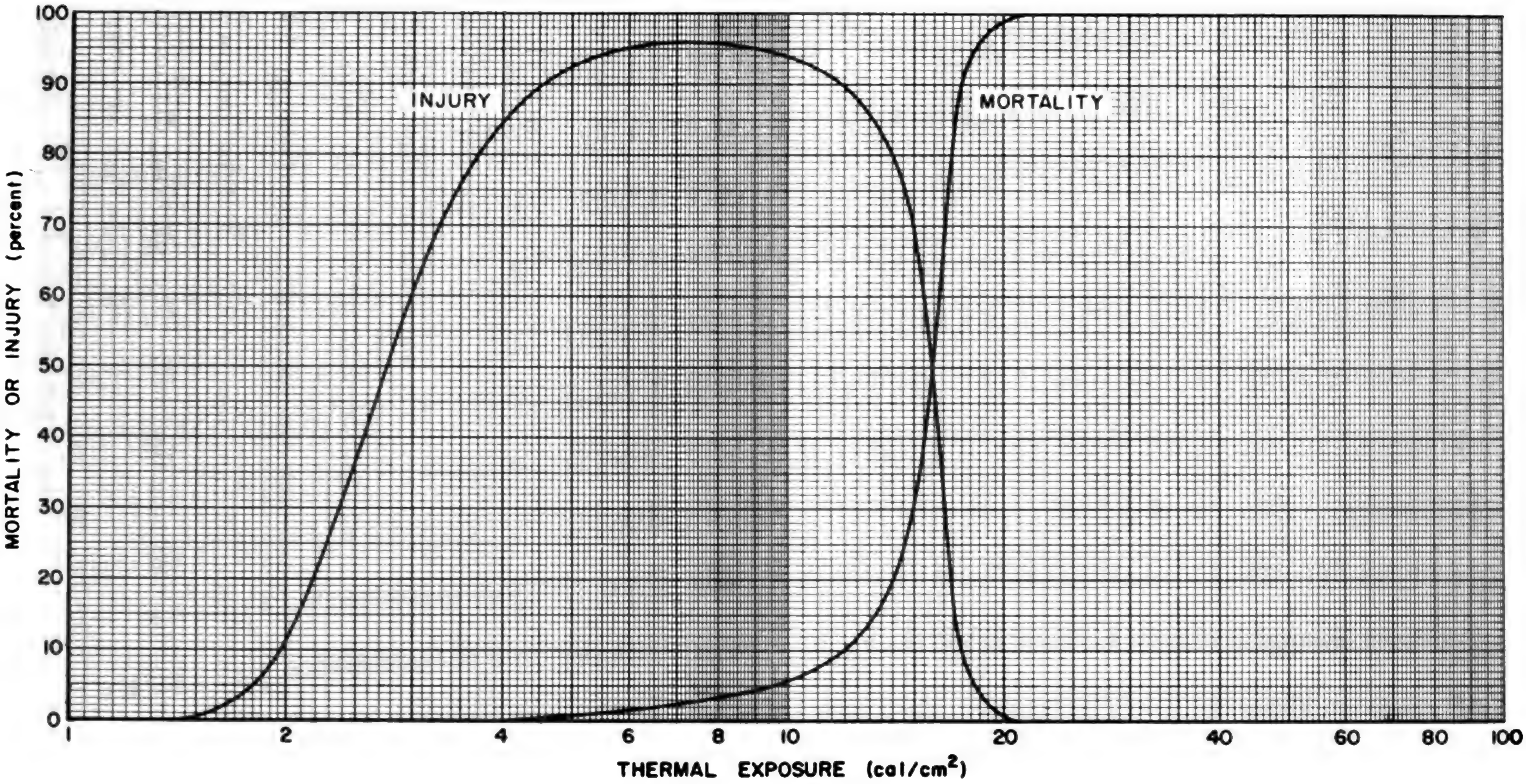
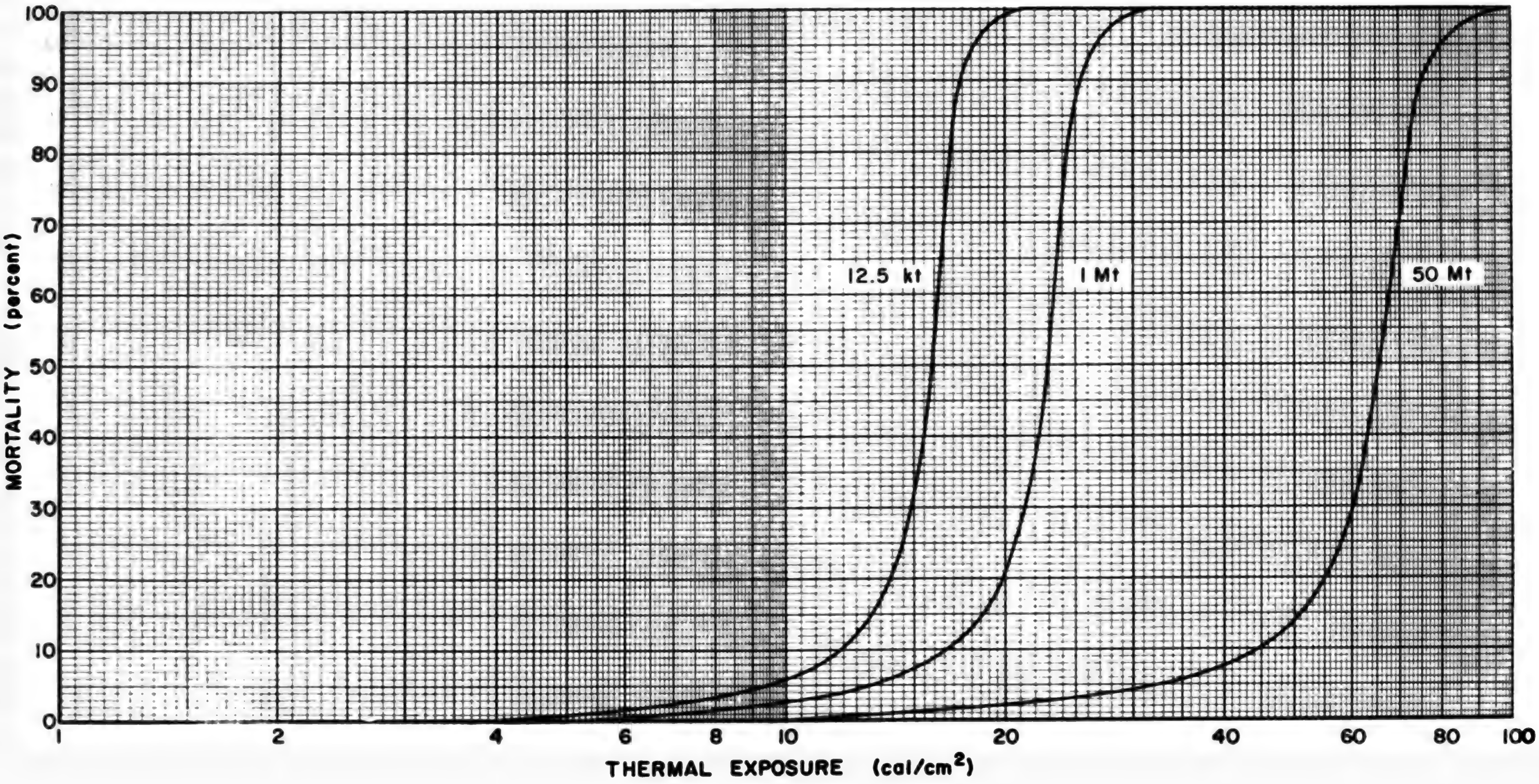


FIG. 24

PROMPT-THERMAL MORTALITY CURVES FROM SURFACE BURSTS FOR OUTSIDE-UNSHIELDED PERSONS



condition for development of firestorms. High ambient winds usually cause conflagrations to develop, as noted above.

B. FIRE MORTALITY CURVES

Fires in nine German cities were analyzed in detail to provide data for the development of fire mortality curves. Similar procedures were applied to the fires caused by the nuclear detonation over Hiroshima. Earlier work in this area indicated a correlation between the peak power density (maximum rate of energy release per unit area of the fire bed) and the percent fire mortality for the population at hazard within the fire area.* The four general groupings of construction or shielding categories given by the curves in Fig. 30 are the result of investigating this correlation (Refs. 14 through 18). The general groupings and breakdowns by shielding category are given below:

1) Heavy Construction
   a) Seismic Reinforced-Concrete Buildings
   b) Nonseismic Reinforced-Concrete Buildings (Basements)

2) Medium Construction
   a) Nonseismic Reinforced-Concrete Buildings (Above Ground)
   b) Heavy Steel-Frame Buildings (Basements)†
   c) Light Steel-Frame Buildings (Basements)†
   d) Heavy Brick Wall-Bearing Buildings (Basements)†

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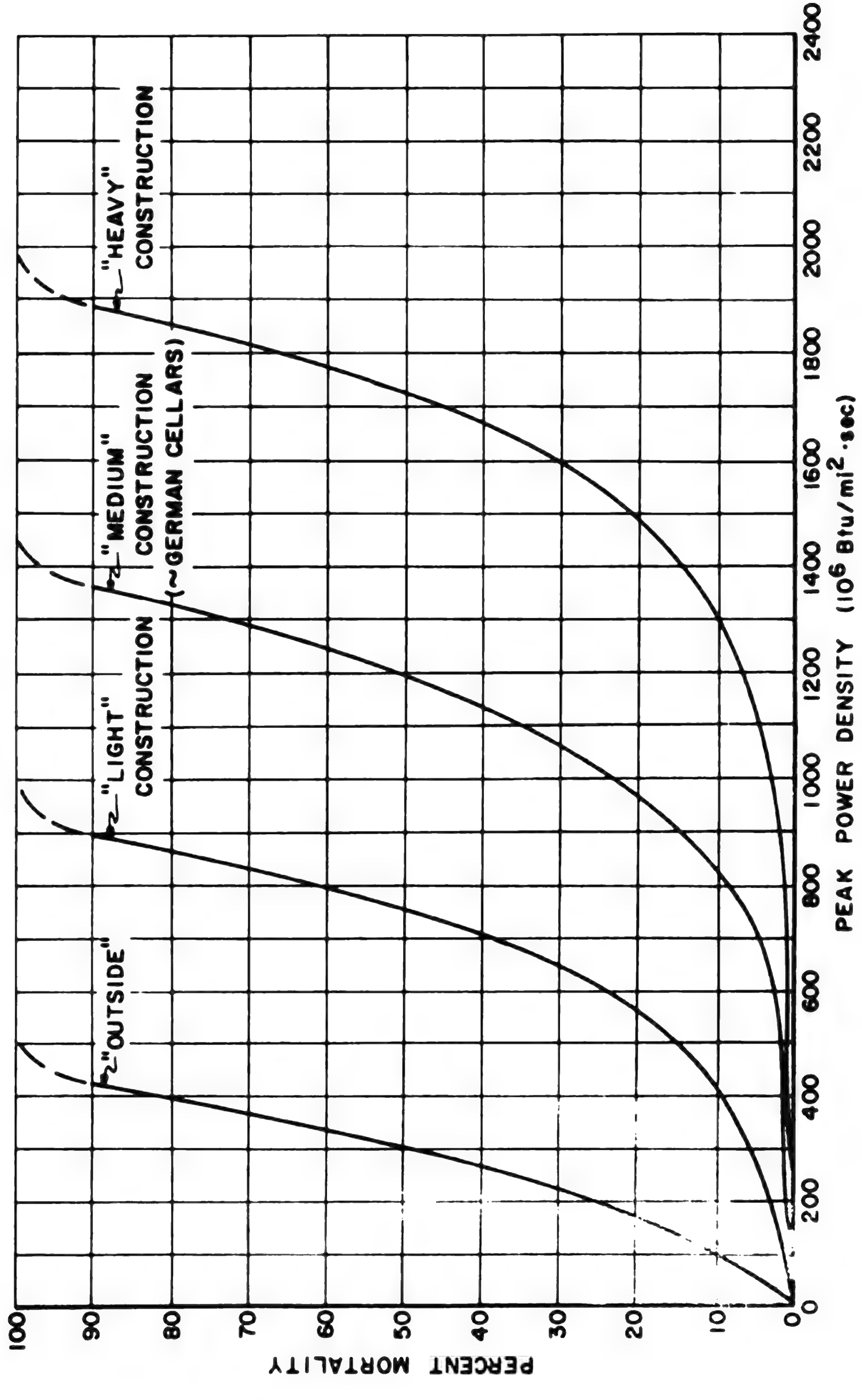
*For application of an earlier form of these relationships to historical cases, see Ref. 13.

†If basements are unavailable, this mortality curve probably lies midway between those for medium and light construction.

FIG. 30

FIRE MORTALITY CURVES



3) Light Construction

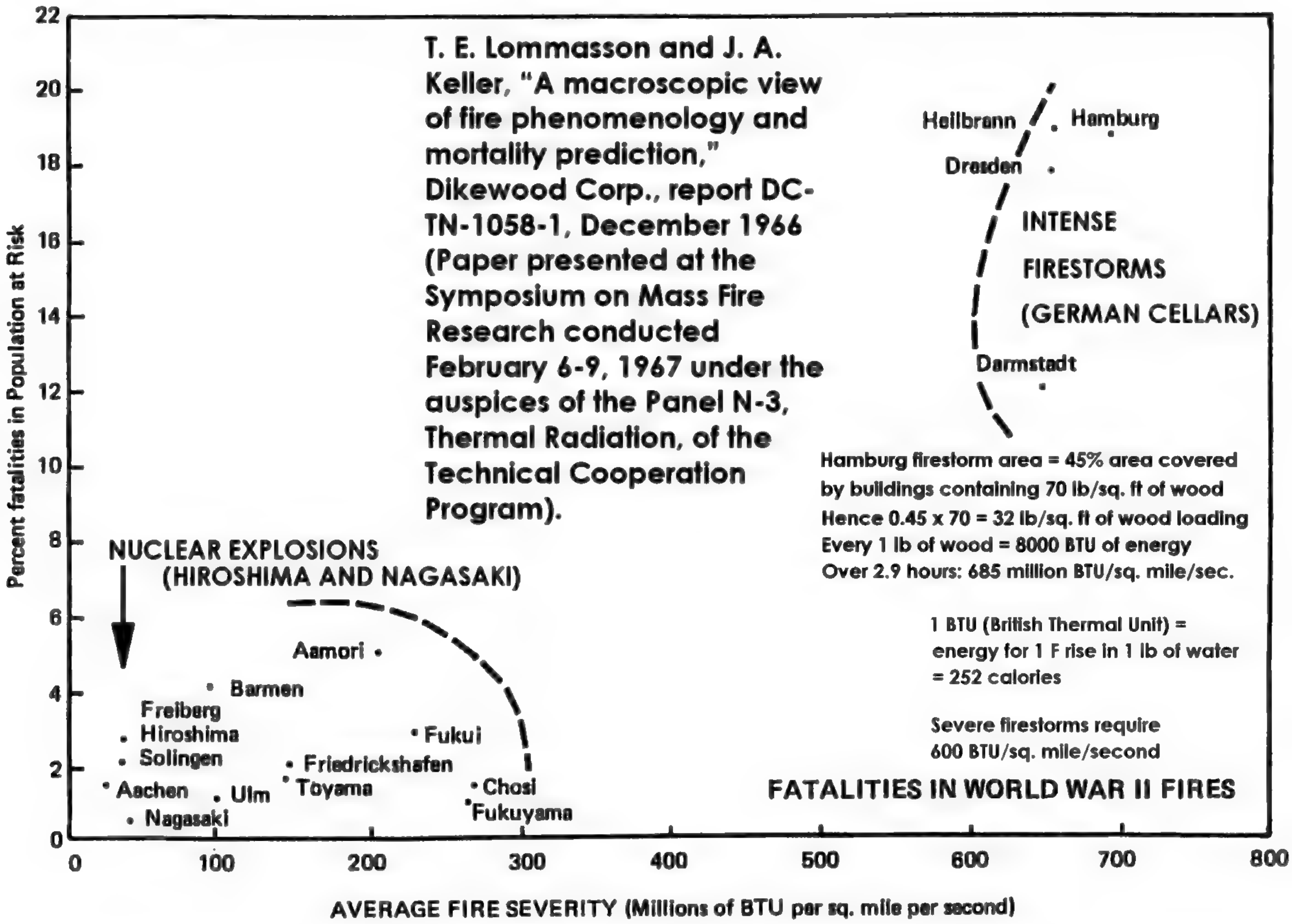
a) Brick Residential Buildings

b) Wood-Frame Buildings (Basements)*

4) Outside

a) Outside-Shielded Category

b) Outside-Unshielded Category



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*If basements are unavailable, this mortality curve probably lies midway between those for light construction and the outside category.
between those for medium and light construction.

Figure 7.33a. Thermal effects on wood-frame house 1 second after explosion (about 25 cal/sq cm).

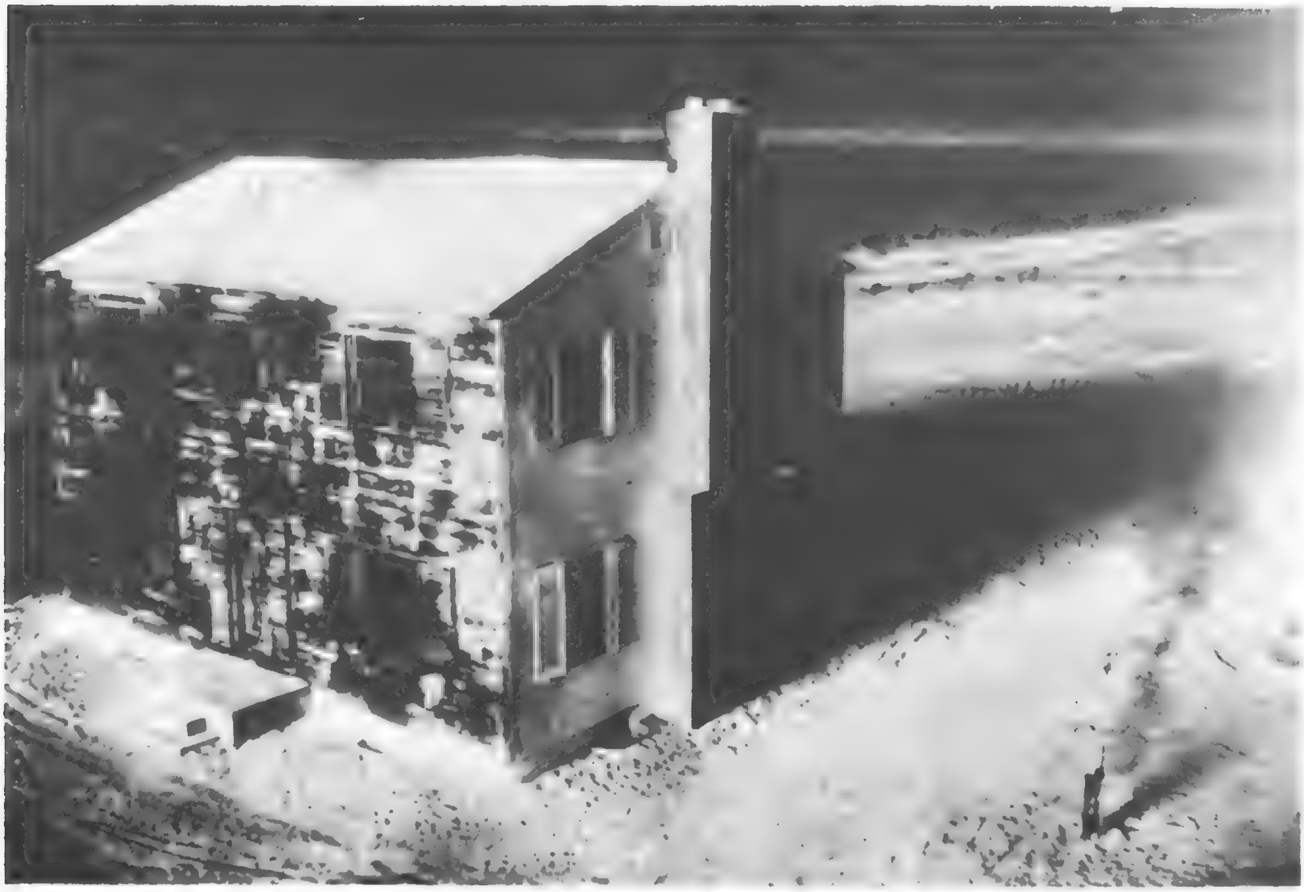

Figure 7.33b. Thermal effects on wood-frame house about ¾ second later.

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Editorial Comments

If clothing ignites, education should be so thorough that the immediate reaction is "smother the flames."

Every child should be trained to roll on the floor if his clothes catch fire, and every adult should know how to extinguish flames with the nearest material at hand - his own coat, a rug, or a blanket. They should know, in advance of the actual emergency, the importance of bringing the coat (or whatever else they are using) across the face to fend the flames and smoke away from the vital air passages.

37

Dr. Edward L. Alpen (U. S. Naval Radiological Defense Laboratory): About this question of the spectral dependence of radiant energy, I think Dr. Haynes may have given you the impression that white light does the trick. There is later work which tends to refute that. The work done at Virginia used cut-off filters. The effectiveness of all energy above a certain wave length or below a certain wave length was measured. At the upper end the most effective and the least effective were mixed together and made it appear that infrared was not too good in producing burns. When you subdivide the spectrum, the most effective energy in producing a flash burn is the infrared above about 1.2 microns.

The importance of this, and the only reason I make an issue of it, is that a very important source of flash burn, both in civilian life and under wartime disaster conditions, is radiant energy burns from flaming sources. We have done a great deal of research on this subject for the U. S. Forest Service, because radiant energy burns are important in forest fires.

Energy in the wave lengths of 0.6 to 0.8 micron is about one-eighth as destructive as the rest of the spectrum. But long wave length radiation above one micron is extremely destructive, and the most effective of all.

49

Dr. Alpen: Anything that shields out radiation above one micron is extremely effective in preventing burns to the skin.

50

THE BURN SURFACE AS A PARASITE

WATER LOSS, CALORIC DEMANDS, AND THERAPEUTIC IMPLICATIONS

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Baltimore, Maryland

Water is Lost through Burned Skin*

A burn may be thought of as a parasite, drawing from its host water, protein, and other substances which the host needs for its survival. An uninjured person who is not perspiring may lose from 1.15 to 2.0 quarts of fluid a day through his lungs and skin,[1,2,4,5,14] depending on the temperature of his environment. The fluid losses from a burn wound are far in excess of those from intact skin and may amount to 2 gallons per day, or more if the burn is large enough.[2,5,6,17,21] If, during the first 48 hours after injury, no more fluid is given to an extensively burned patient than he would need in health, the uncompensated loss of fluid from his circulation may cause shock, and if sufficiently severe, death. After the first 48 hours, the danger of shock is lessened, but inordinate fluid losses will continue from the burn surface.

Heat is Lost Necessitating a High Food Intake

To make matters worse, evaporation of moisture from the wound surface saps not only the body's water stores but its energy stores as well. When water evaporates from the burned surface, cooling results and the body loses heat. The larger the burn wound, the more water loss and the more heat or energy loss.**

*The majority of the paragraph headings in this article were supplied by the editors.

**Although the core temperature of the human body approximates 39.5°C, the body surface averages only 32°C. At any given temperature, water can be evaporated by applying a certain number of heat calories. At 32°C, one gram of water can be evaporated if 0.579 large calories of heat is invested.

How Can the Fluid and Heat Losses Be Diminished?

Unfortunately, we do not possess at present any practical means of reducing the loss of water from a burn to the level of loss from intact skin on a scale suitable for use following a holocaust.

Think Plastic Wrap as Wound Dressing for Thermal Burns

ACEP (American College of Emergency Physicians) News
http://www.acep.org/content.aspx?id=40462

August 2008
By Patrice Wendling
Elsevier Global Medical News

CHICAGO - Ordinary household plastic wrap makes an excellent, biologically safe wound dressing for patients with thermal burns en route to the emergency department or burn unit.

The Burn Treatment Center at the University of Iowa Hospitals and Clinics, Iowa City, has advocated prehospital and first-aid use of ordinary plastic wrap or cling film on burn wounds for almost two decades with very positive results, Edwin Clopton, a paramedic and ED technician, explained during a poster session at the annual meeting of the American Burn Association.

"Virtually every ambulance in Iowa has a roll of plastic wrap in the back," Mr. Clopton said in an interview. "We just wanted to get the word out about the success we've had using plastic wrap for burn wounds," he said.

Dr. G. Patrick Kealey, newly appointed ABA president and director of emergency general surgery at the University of Iowa Hospital and Clinics, said in an interview that plastic wrap reduces pain, wound contamination, and fluid losses. Furthermore, it's inexpensive, widely available, nontoxic, and transparent, which allows for wound monitoring without dressing removal.

"I can't recall a single incident of its causing trouble for the patients," Dr. Kealey said. "We started using it as an answer to the problem of how to create a field dressing that met those criteria. I suppose that the use of plastic wrap has spread from here out to the rest of our referral base."

Although protocols vary between different localities, plastic wrap is typically used for partial- and full-thickness thermal burns, but not superficial or chemical burns. It is applied in a single layer directly to the wound surface without ointment or dressing under the plastic and then secured loosely with roller gauze, as needed.

Because plastic wrap is extruded at temperatures in excess of 150° C, it is sterile as manufactured and handled in such a way that there is minimal opportunity for contamination before it is unrolled for use, said Mr. Clopton of the emergency care unit at Mercy Hospital, Iowa City. However, it's best to unwind and discard the outermost layer of plastic from the roll to expose a clean surface.

EVAPORATION OF WATER FROM 3RD DEGREE BURNS AREAS

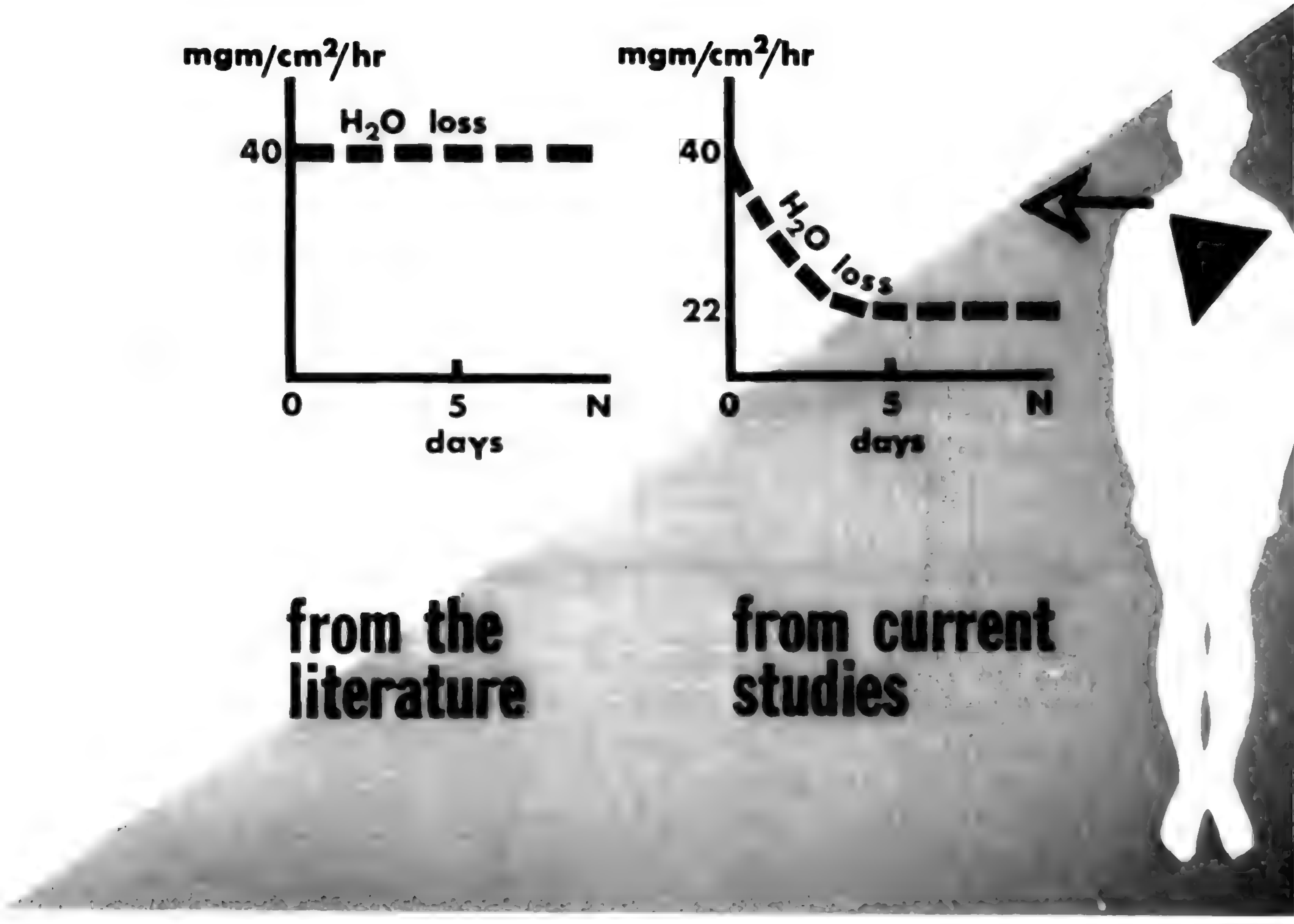

Fig. 2. Schema illustrating the gradual decrease in eschar transmissivity with time.

SOME PRINCIPLES OF PROTECTION AGAINST BURNS FROM FLAME AND INCENDIARY AGENTS

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Biophysics Laboratory

Edgewood Arsenal, Maryland

I. Flame Agents

A. Their Nature

Flame agents are special blends of petroleum products, usually in thickened form, that ignite easily and can be projected to a target. Methods for the throwing of flame were devised by the Greeks in 429 B.C. (Siege of Plataea) when destructive flammable mixtures of pitch and sulfur were used. "Greek fire" composed of pitch, sulfur, and naptha, together with a method of projecting it through brass tubes or in red-hot balls of stone or iron, were developed about 670 A.D. in the arsenals of Constantinople. A type of flame thrower used on ships was constructed, with pressure furnished by a water engine. It is thought by some that this contained an igniting substance (quicklime or phosphide) that acted in the presence of water, but this has not been proven. The Germans in World War I were the first to use flame projectors. All combatting nations developed and used flame throwers extensively in World War II. Fire bombs were first used in the second world war.

<u>M1 (Napalm)</u>. M1 thickener is a coprecipitated aluminum soap. The name was derived from the <u>nap</u>hthenic and p<u>alm</u>itic acids that were its major constituents.

<u>Napalm B</u>, used by the Air Force, is intended as a replacement for the M2 thickener. It is not true napalm, being composed of polystyrene, gasoline, and benzene. It is not a gel, but is a sticky, visco-elastic liquid. It has a longer burning time than the M1, M2, and M4 thickened fuels, and, therefore, possibly better incendiary action.

Unlike the M1, M2, and M4 thickeners, which can be quite easily brushed off the skin, the Napalm B is sticky and the polystyrene itself burns, its burning time being longer than that of the petroleum products. Therefore, this does have the required characteristics to produce more severe burns than unthickened fuel.

B. Defense Against Flame Agents (Protective Coverings)

The primary objective of individual defense against flame[5] is to keep particles of burning fuel off the person. The use of almost any available cover when a flame attack appears imminent is recommended. Troops are instructed to remain covered with no skin exposed until after the flash and flame in the high heat zone have been dissipated and then throw off the cover and remove any burning particles from their clothing. Blankets or items such as an army field jacket have been shown to give real protection. Two thicknesses of the Army shelter half tent will hold burning fuel for more than 10 seconds. Tent canvas and truck tarpaulins which have been treated with fire-resistant material will withstand direct hits with burning fuel and will hold the burning particles for sufficient time (more than 30 seconds) to permit personnel to escape. Foxhole covers improvised of brush with as little as 2 inches of earth on top will successfully withstand burning fuel. The Army plastic poncho is not a satisfactory cover because it melts rapidly and burns when hit with flaming fuel. This would increase the severity of burns received by an individual. Foxholes and weapon positions can be modified to afford adequate protection for anything except a direct hit with a fire bomb.

II. Incendiaries:[19]

A. Their Nature

Incendiary agents are compositions of chemical substances designed for use in the planned destruction of buildings, property, and materiel by fire. They burn with an intense localized heat. They are very difficult to extinguish and are capable of setting fire to materials that normally do not ignite or burn readily. Although there are tactical applications for incendiary munitions, they have played primarily a strategic role in modern warfare. The first practical model of an incendiary artillery shell was developed by the French in 1878.

The mechanics of fire-starting involve three essentials in addition to a source of oxygen: (1) Source of heat acting as a "match" to initiate the fire, (2) A combustible material which serves as the kindling, and (3) The fuel. The incendiary supplies the match and the kindling, and the target supplies the fuel. Modern military incendiaries may be divided into three categories: (1) Oil, (2) Metal, and (3) Combination of oil and metal.

The incendiary bomb (as distinguished from the fire bomb filled with thickened fuel) has been considered a strategic rather than a tactical weapon and has been used mainly against rear-area and supply installations. Incendiary shells and incendiary grenades are primarily tactical weapons, as are the flame munitions (fire bombs and flame throwers). Large incendiary bombs are used against point targets such as air bases and factories. Small incendiary bombs are usually dropped in clusters.

2. Metal incendiaries include those consisting of magnesium in various forms, and powdered or granular aluminum mixed with powdered iron oxide. Magnesium is a soft metal which, when raised to its ignition temperature (623° = 1,150°F), burns vigorously in air. Magnesium has a burning temperature of about 1,982°C (3,600°F) depending upon the rate of heat dissipation, rate of burning, and other factors. Its melting point is 651°C, so it melts as it burns. The liquid metal, burning as it flows, drops to lower levels, igniting combustible materials in its path. Burning stops if oxygen is prevented from reaching the metal or if the metal is cooled below the ignition temperature. Magnesium does not have the highest heat of combustion of the metals, but none of the other metals have been successfully used singly as air-combustible incendiaries. In massive form, magnesium is difficult to ignite. Therefore, a hollow core in the bomb is packed with thermate and an easily ignited mixture which supplies its own oxygen and burns at a very high temperature.[19]

a. Thermite incendiaries.[19] Thermite is essentially a mixture of about 73 per cent powdered ferric oxide (Fe_2O_3) and 27 per cent powdered or granular aluminum. The aluminum has a higher affinity for oxygen than iron has, and if a mixture of iron oxide and aluminum powder is raised to the combustion temperature of aluminum, an intense reaction occurs: $Fe_2O_3 + 2AL \rightarrow AL_2O_3 + Fe$ + heat. Under favorable conditions, the thermite reaction produces temperatures of about 2,200°C (3,922°F). This is high enough to turn the newly formed metallic iron into a white hot liquid which acts as a heat reservoir to prolong and to spread the heat or igniting action.

b. Thermate incendiaries.[19] The thermate mixture composed of thermite with various additives is used as a component in igniter compositions for magnesium bombs and as a filler in incendiary hand grenades. There are several different types of thermate. The more recent ones contain barium nitrate as an oxidizer. The thermate core is ignited by the primer. This burning core then melts and ignites the magnesium alloy body. The incendiary action is localized, since there is little scattering action.

B. Defense Against Incendiaries (Fire Fighting)

Defense against incendiaries, as outlined in a U.S. Army publication[5] is summarized as follows: Incendiary bomb clusters may contain a percentage of high explosive incendiary bombs so precautions should include this possibility. A brick wall offers adequate protection against small explosive incendiary bombs. Incendiary bombs can be scooped up with shovels and thrown into a place where no damage will be done. Sandbags and sandmats can smother bombs and reduce effects of fragmentation. Loose sand helps to smother fires started by the bomb. Whether or not sandbags and sandmats are used, water or fire extinguishers are employed immediately. Water extinguishers should not be used directly on oil, because this tends to spread the fire, but water can be used against incendiaries such as phosphorus. Water confines the spread of the fire by wetting down the surrounding area, but despite some published advice to the contrary,[5] water should not be used on magnesium incendiaries, because of the resulting explosive effect. If hot enough, phosphorus particles ignite when exposed to oxygen in the air. Control them by keeping them covered, preferably with water.

III. White Phosphorus

White phosphorus is often classified as an incendiary, but is actually used primarily as a screening smoke or as an igniter for other munitions. At a sufficiently high temperature, it reacts with air and water vapor to produce a dense cloud of phosphorus pentoxide, a very effective screen. It has two disadvantages for this use. One is that because of its high heat of combustion, it tends to rise in a pillar-like mass, especially in still air. The other is that it is very brittle, and the exploding munitions in which it is used break it into very small particles that burn very rapidly. These disadvantages were somewhat overcome by the development of plasticized white phosphorus (PWP). PWP is produced by melting WP and stirring it into cold water, resulting in a slurry of WP granules about 0.5 mm in diameter. The slurry is then mixed with a very viscous solution of synthetic rubber, thus coating the granules with a film of rubber and separating them from each other. When PWP is dispersed by exploding munitions, it does not break into such small particles, the burning rate is slowed, and the tendency of the smoke to pillar is reduced. Despite the fact that the characteristics of WP and PWP somewhat limit their applications as screening smokes, their military uses include incendiary and antipersonnel effects, because burning particles of WP can start fires in many combustible materials and can produce burns.

IV. Medical Aspects

The one agent about which the most confusion seems to exist is white phosphorus. Its melting point is very low, 44°C (111°F). When it is placed in munitions it is in solid form, and when the munition detonates some will be liquified because of heat.

When white phosphorus is exposed to air, it burns if the temperature is over 34°C (93°F). Burning white phosphorus yields phosphorus pentoxide which combines with water to yield phosphoric acid.

In practice, white phosphorus particles are removed, and the burns treated as any burns. It is often stated or implied that white phosphorus burns are much "more severe" than other burns, but this depends on the method of quantitation and the form of the white phosphorus encountered. Particulate white phosphorus will indeed cause third-degree burns, but these may be scattered small burns. There are few other burns that are combined with explosive fragmentation wounds. Liquid white phosphorus is difficult to remove, penetrates clothing and indeed can cause severe burns. However, unignited particulate white phosphorus can easily be brushed off by the alert individual unless it is partly imbedded.

In 1945, Walker et al., studied the effects of ignited 25 mg. white phosphorus pellets.[29] These burned for about 22 seconds on both glass and the skin of an anesthetized pig. They found that when WP was burned on glass, 79 per cent of the phosphorus was found in the smoke, and when burned on skin, 66 per cent of the phosphorus was in the smoke. The residue on glass contained 9 per cent of the phosphorus as acid, while on the skin, 24 per cent was acid. On glass, about 33 per cent of this acid was orthophosphoric acid, whereas on skin, 93 per cent was orthophosphoric acid. These differences were attributed to available water. About 2.0 mg of the WP was converted to red phosphorus on glass, and about 1.8 mg on skin. An average of 2.7 mg of the phosphorus entered the skin as orthophosphoric acid.

Copper sulfate treatment of white phosphorus injuries and its complication: Traditionally, 5 per cent copper sulfate solution has been applied to white phosphorus injuries. This coats the white phosphorus particles so that they are easily identified and removed, and prevents contact with atmospheric oxygen, so that ignition is prevented. There have been several cases reported of hemolysis* in white-phosphorus-burn patients so treated.

*hemolysis = breakdown of red blood cells

V. Summary

Prompt defensive and corrective action makes a very great difference in the severity of injuries resulting from any of these agents.

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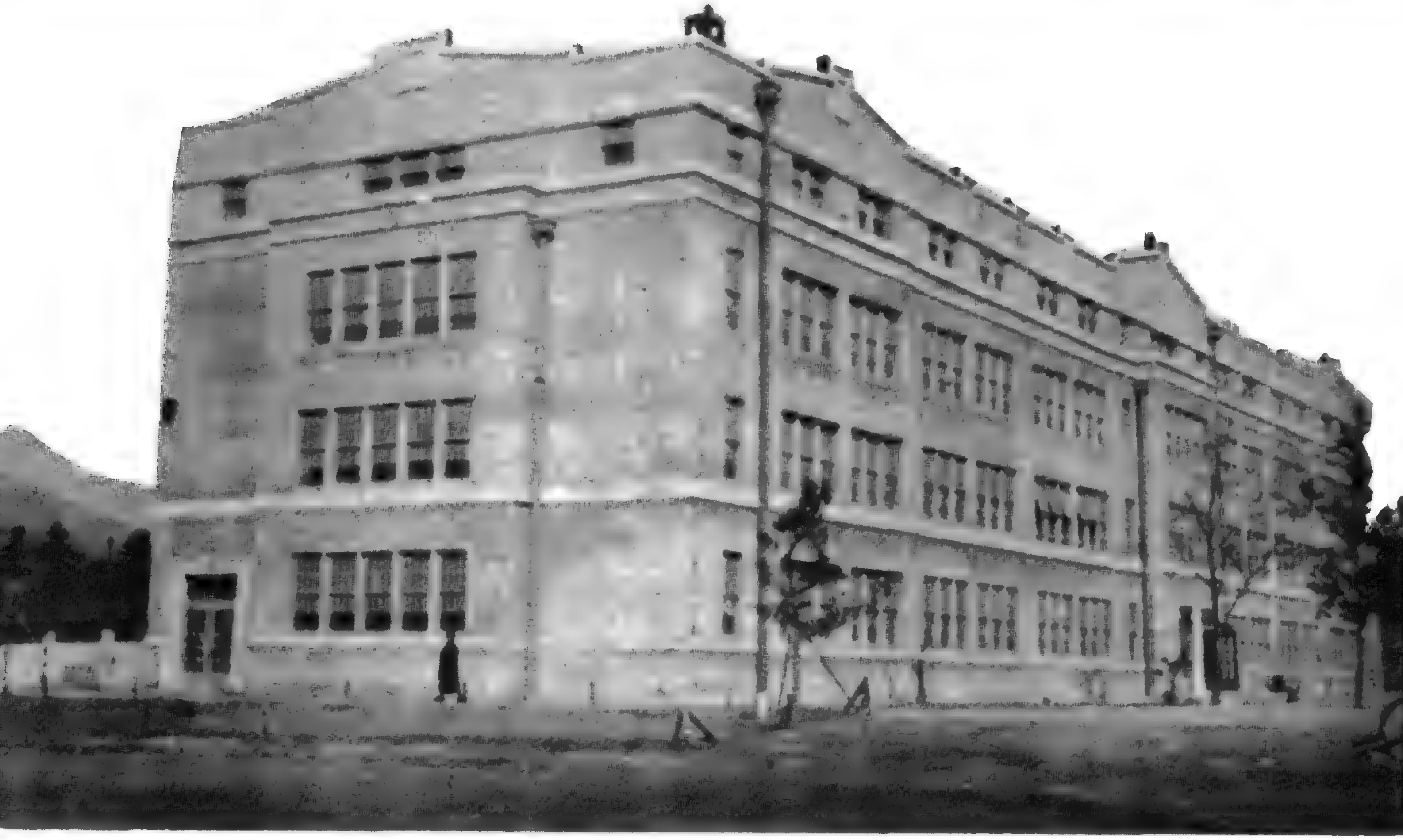
Nihonbashi District in Tokyo after attack of March 9, 1945, with AN-M69 incendiary bombs.

Nagasaki Medical
500 m
YAMASATOMACHI
Prison
OKAMACHI
Baseball
park
Stadium
Probable rice mills and storage
MATSUYAMACHŌ
SHIROYAMACHŌ
NAGASAKI
Sanitorium
Municipal
Tenement
District

15
2000
12
1000
GROUND ZERO
17
16
20
18
22



Chinzei Middle School before the explosion.

Chinzei Middle School after the explosion.
500 meters from the center.

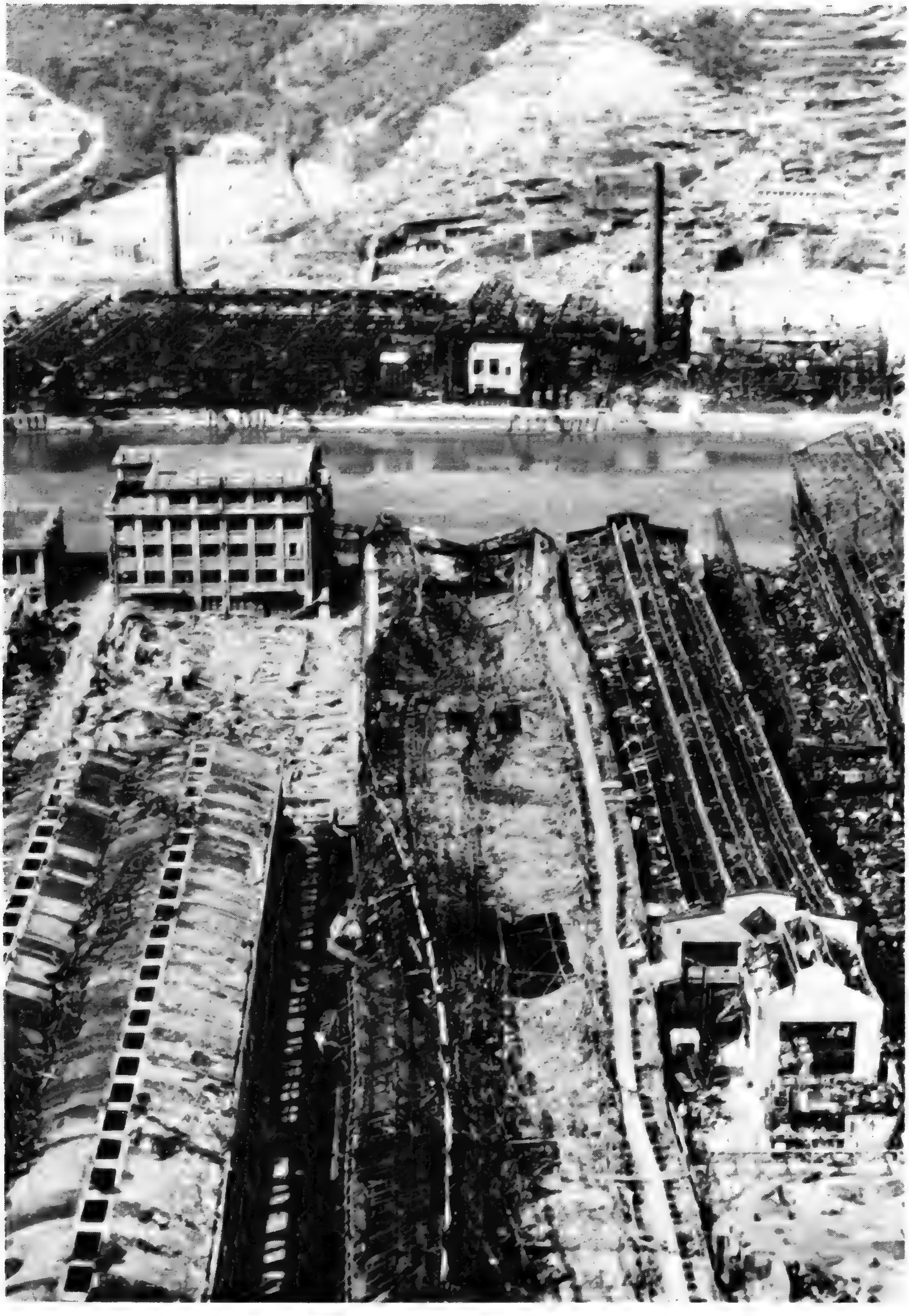


Figure 5.91. At left and back of center is a multistory, steel-frame building (0.85 mile from ground zero at Nagasaki).

Tunnel shelters in hillside, very close to ground zero in Nagasaki, protected the occupants from blast, thermal radiation, and immediate nuclear radiation.

3rd October, 1963.

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RESEARCH ON BLAST EFFECTS IN TUNNELS

With Special Reference to the Use of London Tubes as Shelter

by F. H. Pavry

Summary and Conclusions

The use of the London tube railways as shelter from nuclear weapons raises many problems, and considerable discussion of some aspects has taken place from time to time. But - until the results of the research here described were available - no one was able to say with any certainty whether the tubes would provide relatively safe shelter or not.

The more recent research here described showed for the first time that a person sheltering in a tube would be exposed to a blast pressure only about $\frac{1}{3}$ as great as he would be exposed to if he was above ground. (In addition, of course, he would be fully protected from fallout in the tube.)

Large-Scale Field Test ($^1/40$) at Suffield, Alberta

The test is fully described in an A.W.R.E. report(6). The decision of the Canadian Defence Research Board to explode very large amounts of high explosive provided a medium for a variety of target-response trials that was welcome at a time when nuclear tests in Australia were suspended. A.W.R.E. used the 100-ton explosion in 1961 to test, among other items, the model length of the London tube, at $^1/40$th scale, that had already been tested at $^1/117$ scale.

Blast Entry from Stations

There was remarkable agreement with the $^1/117$th scale trials: "maximum overpressure in the train tunnels was of the order of $\frac{1}{3}$rd the corresponding peak shock overpressure in the incident blast. The pressures in the stations were about $^1/6$th those in the corresponding incident blast .... ".

(6) $^1/40$th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System. A.W.R.E. Report E2/62. (Official Use Only.)

100 ton TNT test on 1000 ft section of London Underground tube at Suffield, Alberta, 3 Aug 1961

Atomic Weapons Research Establishment, "1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System", Report AWRE-E2/62, 1962, Figure 30. (National Archives ES 3/57.)

200 FT FROM GROUND ZERO	400 FT FROM GROUND ZERO
100 PSI OUTSIDE	20 PSI OUTSIDE
30 PSI IN TUBES	7.2 PSI IN TUBES
15 PSI IN TUBE STATIONS	4.3 PSI IN TUBE STATIONS

Aldwych Underground tube station as Blitz shelter, 8 October 1940

THOSE WHO WENT TO SHELTERS began a new kind of night-life. Some took over the Tubes, camping out in this fashion—Elephant and Castle Station, 11th November, 1940.

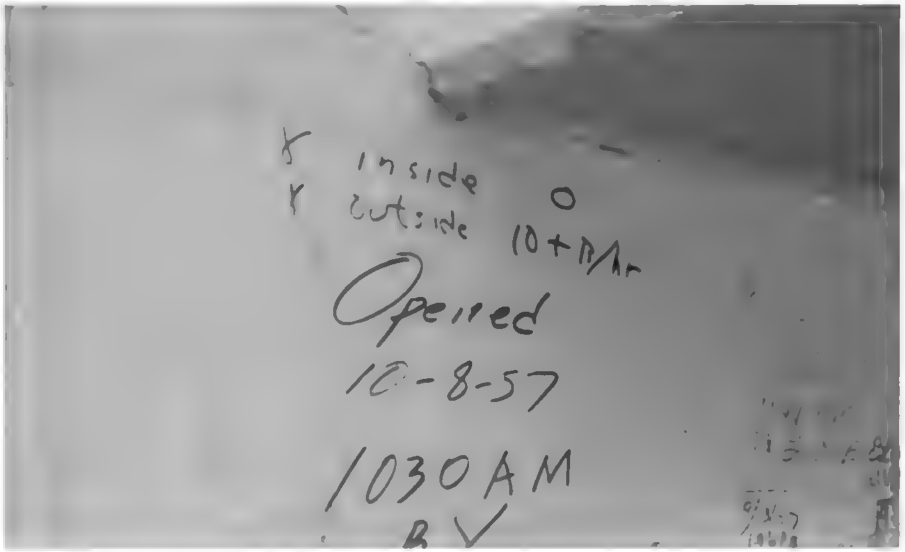
ATTENUATION FACTORS FOR GAMMA RAYS FROM FISSION PRODUCTS AS A FUNCTION OF SHIELD THICKNESS FOR INDICATED MATERIALS*

Attenuation factor	Shield thickness for indicated materials, in.					
	Lead (710 lb/cu ft)	Iron and steel (490 lb/cu ft)	Concrete (144 lb/cu ft)	Earth (100 lb/cu ft)	Water (62.4 lb/cu ft)	Wood (Fir) (3.4 lb/cu ft)
2	0.28	0.7	2.5	3.5	4.8	9.2
4	0.64	1.8	6.6	8.9	13	25
10	1.0	2.7	9.7	13	19	36
50	1.6	4.2	14	20	29	55
100	1.9	4.8	16	23	33	62
1,000	2.7	6.8	22	32	45	88
10,000	3.5	8.8	27	39	56	110
100,000	4.3	11	32	46	70	140

*Data from *The Effects of Nuclear Weapons.*


TRINITY GROUND ZERO:
8000 R/hr at 1 hour
1.4 R/hr at
57 days
11 Sept. 1945

Shelter at ground zero, directly under 11 kt Fitzeau nuclear explosion (500 ft tower)



Test fired on 14 September 1957. Shelter was re-entered on 8 October 1957 when outdoor (ground zero) dose rate was down to about 10 R/hr. No fallout entered the concrete shelter, which was protected by a steel dome hatch (above left). Shelter had 5 feet of earth cover, and was depressed 2 feet into the ground by the shock wave. (W. G. Johnson, A Historical Evaluation of the T-3b Fizeau Bunker.)

SANDIA REPORT

SAND2009-3299
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Printed May 2009

Analysis of Sheltering and Evacuation Strategies for an Urban Nuclear Detonation Scenario

Larry D. Brandt, Ann S. Yoshimura

Executive Summary

A nuclear detonation in an urban area can result in large downwind areas contaminated with radioactive fallout deposition. Early efforts by local responders must define the nature and extent of these areas, and advise the affected population on strategies that will minimize their exposure to radiation. These strategies will involve some combination of sheltering and evacuation actions. Options for shelter-evacuate plans have been analyzed for a 10 kt scenario in Los Angeles.

Results from the analyses documented in this report point to the following conclusions:

- When high quality shelter (protection factor ~10 or greater) is available, shelter-in-place for at least 24 hours is generally preferred over evacuation.
- Early shelter-in-place followed by informed evacuation (where the best evacuation route is employed) can dramatically reduce harmful radiation exposure in cases where high quality shelter is not immediately available.
- Evacuation is of life-saving benefit primarily in those hazardous fallout regions where shelter quality is low and external fallout dose rates are high. These conditions may apply to only small regions within the affected urban region.
- External transit from a low quality shelter to a much higher quality shelter can significantly reduce radiation dose received if the move is done soon after the detonation and if the transit times are short.

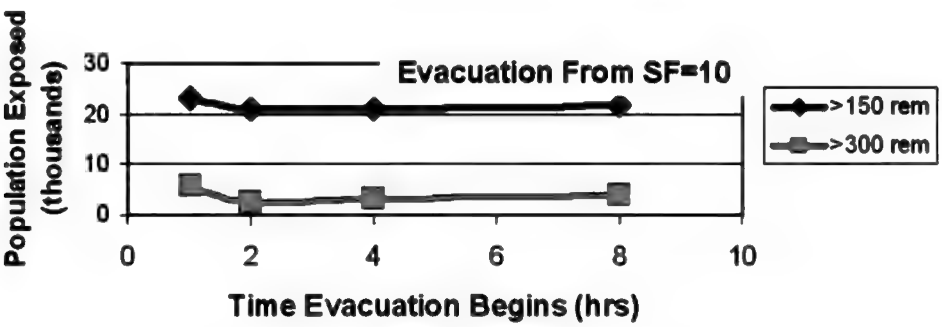
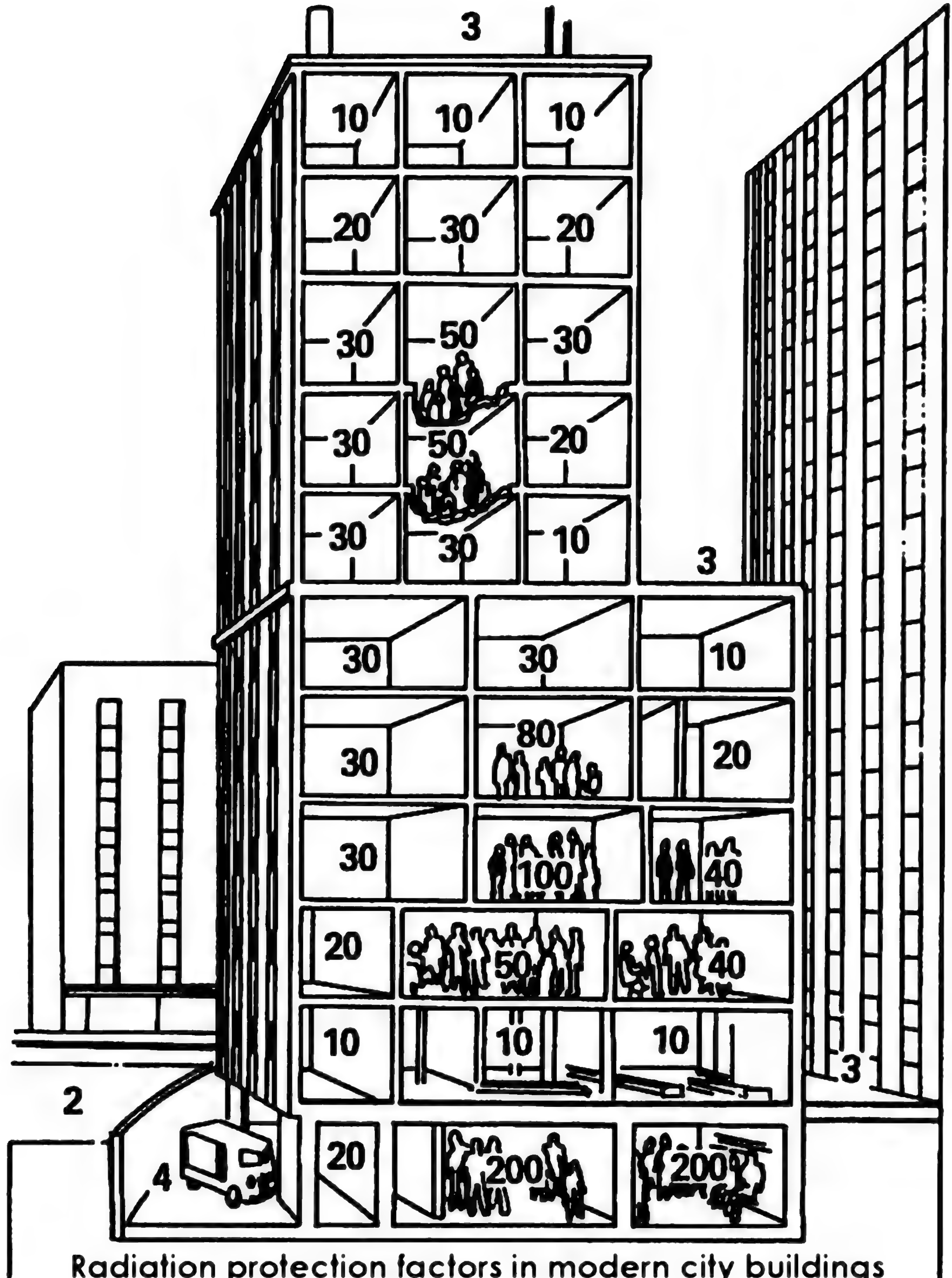


Figure 12. Departure time sensitivities for informed evacuations from shelters with SF=4

Sandia National Laboratories



Radiation protection factors in modern city buildings
DCPA Attack Environment Manual, ch. 6, panel 18

TECHNICAL ANALYSIS REPORT - AFSWP NO. 507

RADIOACTIVE FALL-OUT HAZARDS FROM SURFACE BURSTS OF VERY HIGH YIELD NUCLEAR WEAPONS

by

D. C. Borg
L. D. Gates
T. A. Gibson, Jr.
R. W. Paine, Jr.

MAY 1954

HEADQUARTERS, ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON 13, D. C.

e. Passive defense measures, intelligently applied, can drastically reduce the lethally hazardous areas. A course of action involving the seeking of optimum shelter, followed by evacuation of the contaminated area after a week or ten days, appears to offer the best chance of survival. At the distant downwind areas, as much as 5 to 10 hours after detonation time may be available to take shelter before fall-out commences.

f. Universal use of a simply constructed deep underground shelter, a subway tunnel, or the sub-basement of a large building could eliminate the lethal hazard due to external radiation from fall-out completely, if followed by evacuation from the area when ambient radiation intensities have decayed to levels which will permit this to be done safely.

Table II

Total Isodose Contour: 500r from Fall-out to H+50 Hours

Yield (MT)	15	1	10	60
Downwind extent (mi)	180	52	152	340
Area (mi^2)	5400	470	3880	17,900

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

JUNE 22, 23, 24, 25, AND 26, 1959

PART 1

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
43338 WASHINGTON : 1959

RADIATION CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

	8 mi downwind	60 mi downwind
Average γ Energy		
1 hr	--	1.0 mev
2 hr	--	0.95
1/2 day	--	0.60
1 day	--	0.40
1 week	0.25 mev	0.35
1 mo	0.45	0.65

RADIATION CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

	7 mi downwind	22 mi downwind
Average γ Energy		
1 hr		1.0 mev
2 hr		0.95
1/2 day		0.60
1 day		0.40
1 week		0.35
1 mo		0.65

MYRON HAWKINS:

the induced radiation in uranium 238. We can refer to a British report which indicates that around 60 percent of the total activity at 4 days—activity in this case is the number of disintegrations—is due to the uranium 239 and neptunium 239 that are produced, as the British say, in either large or small weapons. I believe part of the hump on the curves in the early times, say around 4 days, is largely due to this.

Dr. TRIFFET. Yes. I thought this might be an appropriate place to comment on the variation of the average energy. It is clear when you think of shielding, because the effectiveness of shielding depends directly on the average energy radiation from the deposited material. As I mentioned, Dr. Cook at our laboratory has done quite a bit of work on this. What it amounts to is that at one hour the average energy is about one Mev. This appears, by the way, in the tables that are in my written statement but that I did not present orally.

Representative HOLIFIELD. Mev. means?

Dr. TRIFFET. Million electron volts. At 2 hours it drops to 0.95. At a half day, to 0.6. At 1 week it drops to 0.35. Then it begins to go up again. At 1 month, it is 0.65, 2 months 0.65. The meaning of this is simply that there is a period around 1 week when if induced products are important in the bomb, there are a lot of radiations emanating from these, but the energy is low so it operates to reduce the average energy in this period and shielding is immensely more effective.

Strontium 90, for example, has 33-second krypton as its birth predecessor; cesium 137 derives from a fission chain headed up by 22-second iodine, followed by 3.9-minute xenon. Because of their volatile or gaseous ancestry in the fireball or bomb cloud a number of the high-yield fission products are formed in finely divided particles. Some of these are so small that they are not subject to gravitational settling, and in fact they remain suspended in the earth's atmosphere for many years, providing[6] that they reach the stratosphere at the proper latitude. In any event such fission products would be depleted in the local fallout.

For example, the irradiation of uranium^{238} with low Mev. neutrons forms neptunium 239, a 2.3-day radioelement which W. J. Heiman[7] estimates might constitute 50 percent of the residual activity a few days after a bomb detonation.

At higher neutron energies, such as certain types of thermonuclear weapons produce, natural uranium undergoes an (n,2n) reaction which competes with fast fission in U^{238}. The data of R. J. Howerton[8] show that U^{238} has a fission cross section of 0.6 barn from 2 to 6 Mev., thereafter climbing to a plateau value of 1 barn for neutrons up to 14 Mev. At 6.6 Mev. there is a threshold for the (n,2n) reaction and the reaction has a cross section of 1.4 barns in the range of 10 Mev. The ready identification of U^{237} in fallout points to fast fission of U^{238} as a main energy source in high-yield megaton-class weapons.

[6] See E. A. Martell, "Atmospheric Circulation and Deposition of Strontium 90 Debris," Air Force Cambridge Research Center paper (July 1958). See also W. F. Libby, "Radioactive Fallout," speech of Mar. 13, 1959.
[7] Variation of Gamma Radiation Rates for Different Elements Following an Underwater Nuclear Detonation," J. Colloid. Science, 13 (1958), p. 329.
[8] "Reaction Cross Sections of U^{238} in the Low Mev. Range," UCRL 5323 (Aug. 15, 1958).

RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN pages 1689-1691

A. E. R. E. HP/R 2017

ATOMIC ENERGY RESEARCH ESTABLISHMENT

The Radiological Dose to Persons in the U. K. Due to Debris From Nuclear Test Explosions Prior to January 1956

By N. G. Stewart, R. N. Crooks, and Miss E. M. R. Fisher

Activity from Neutron Capture

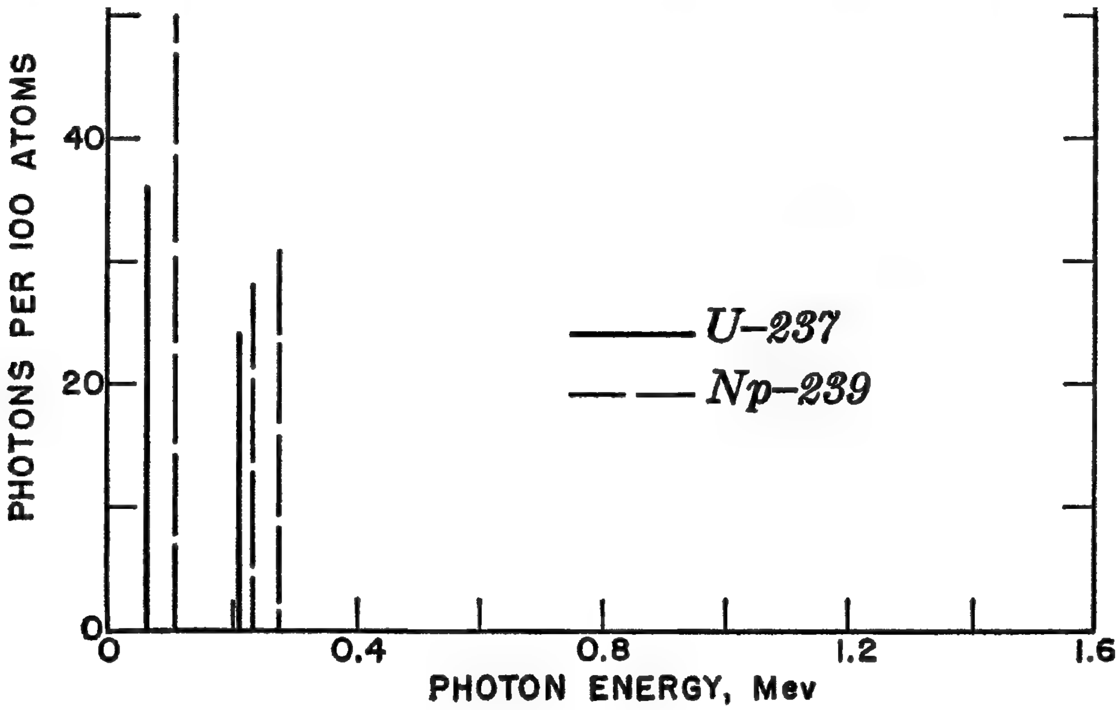
Although several different radioactive elements may be created by the capture of neutrons in materials close to the reacting core of a weapon, the only significant reactions to produce gamma-ray emitters are those associated with the natural uranium which may be used as the tamper material of the bomb.

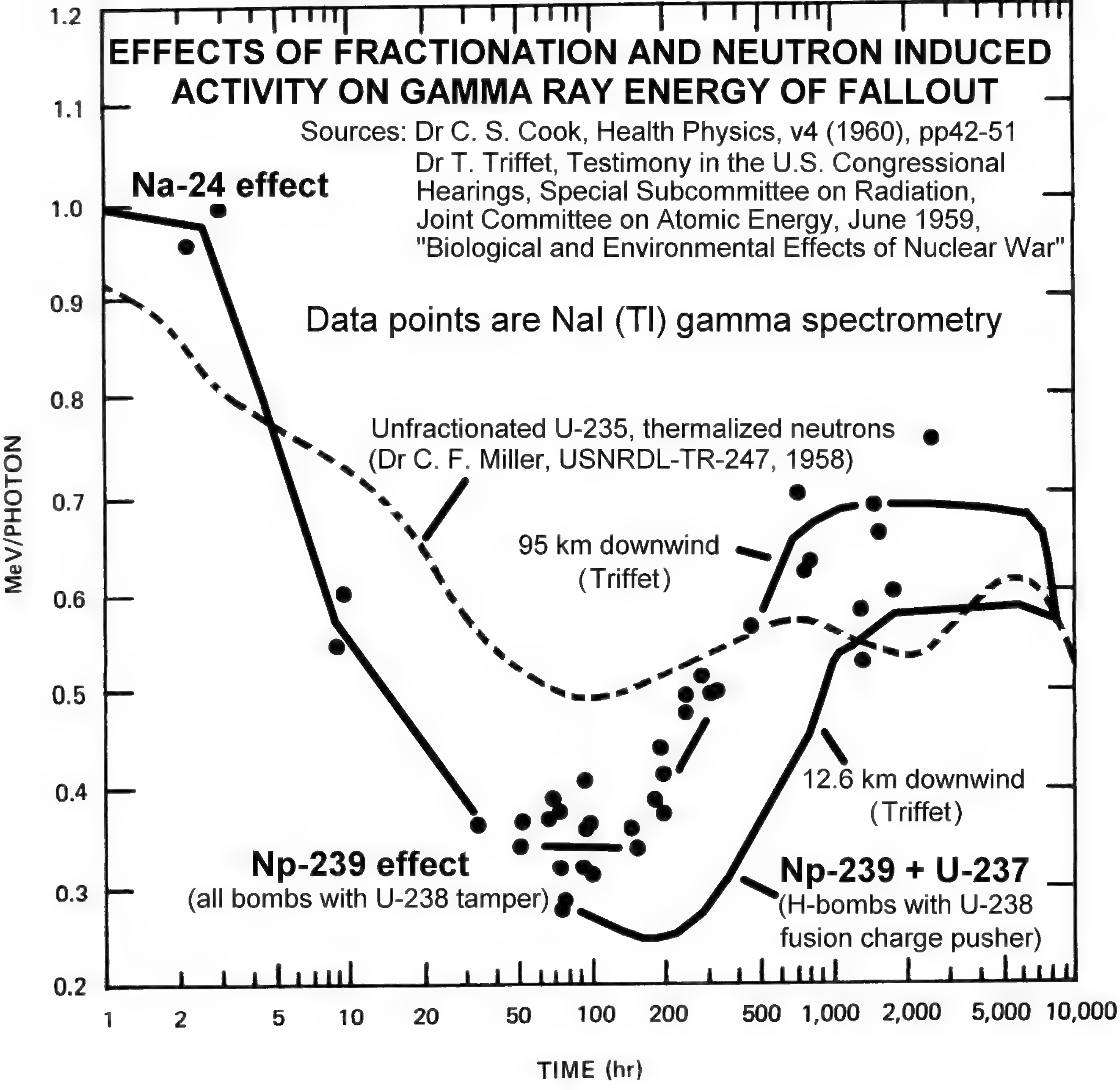
neutron (low energy) + U-238 ⟶ U-239 ⟶ Np-239

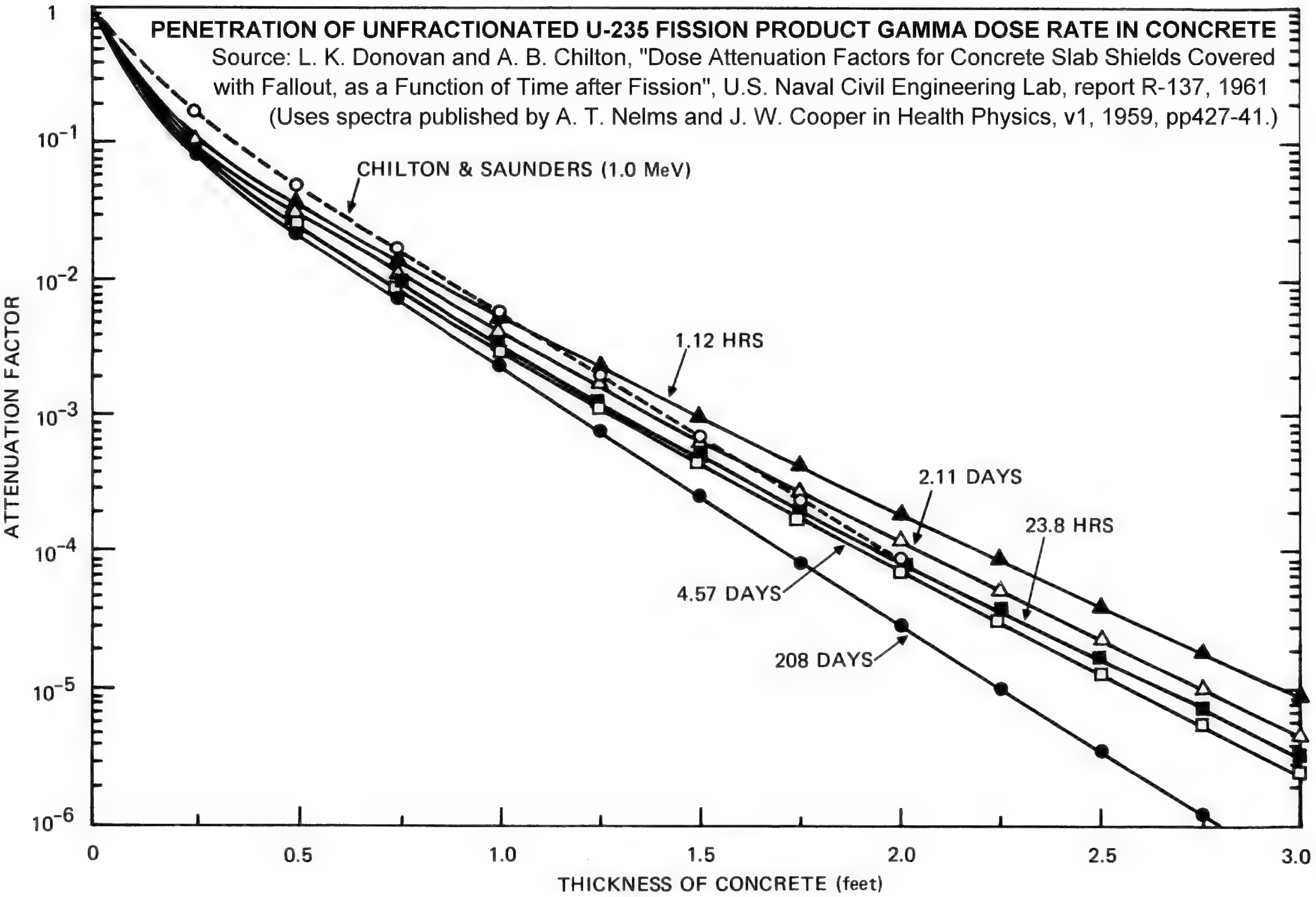
Chemical analysis of the debris shows that in general about one neutron is captured in this way for every fission that occurs, both in nominal bombs and in thermonuclear explosions. The U^{239} decays completely before reaching the U.K. but at four days after time of burst the Np^{239} disintegration rate reaches a peak relative to that of the fission products and accounts for about 60% of the observed activity at that time.

In addition to this, a smaller number of the neutrons in a thermonuclear explosion undergo an (n,2n) reaction with U^{238} to form 6.7 day U^{237} which is also a (β, γ) emitter.

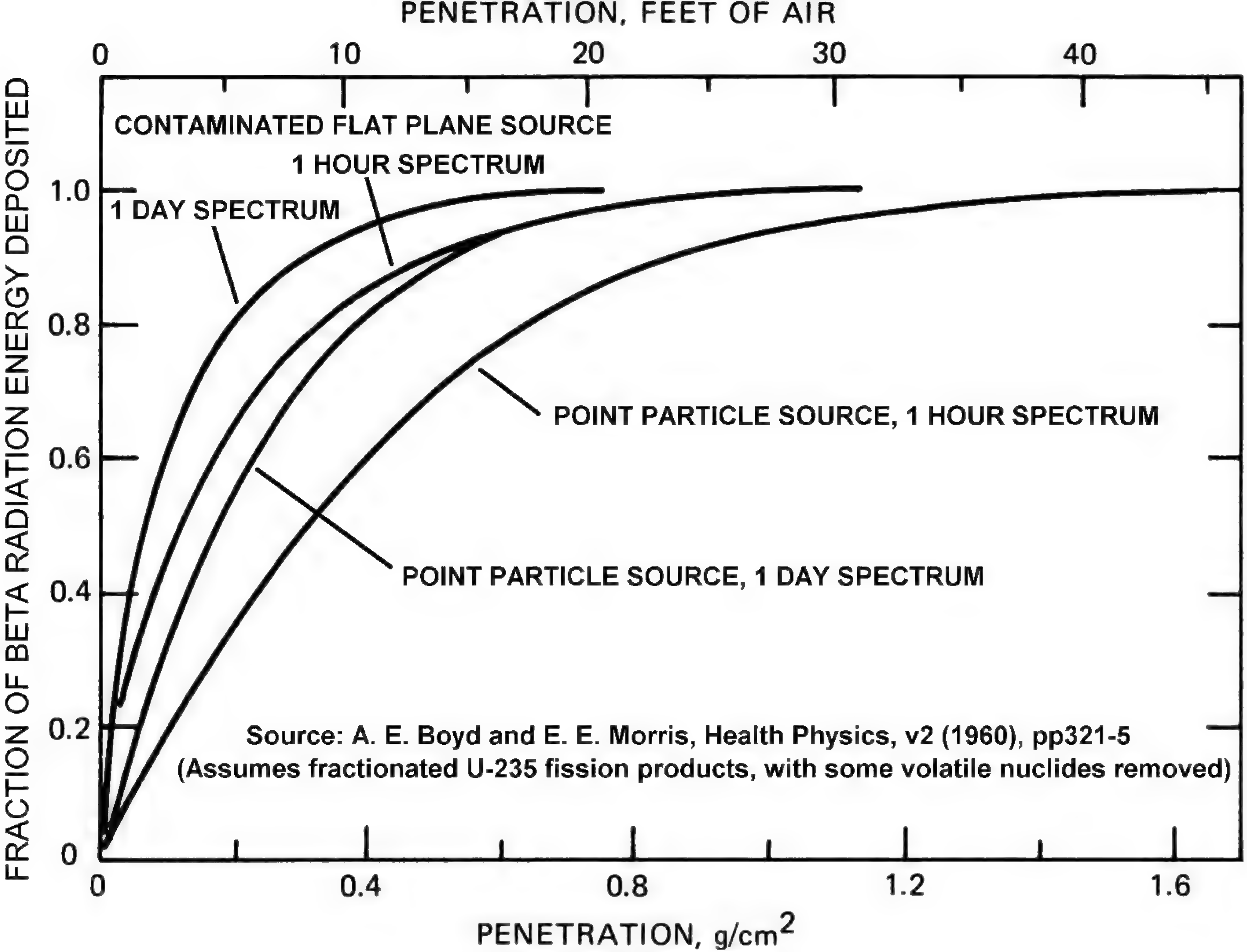
neutron (high energy) + U-238 ⟶ 2 neutrons + U-237



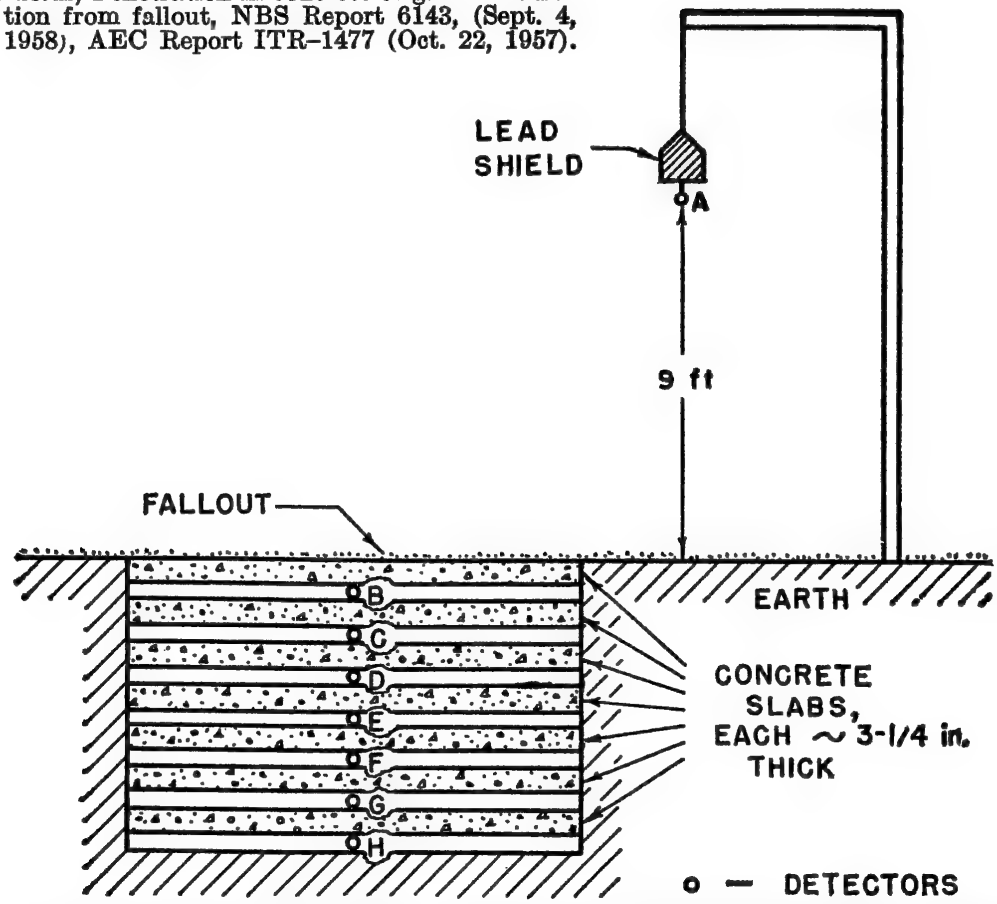

EFFECTS OF FRACTIONATION AND NEUTRON INDUCED ACTIVITY ON GAMMA RAY ENERGY OF FALLOUT
Sources: Dr C. S. Cook, Health Physics, v4 (1960), pp42-51
Dr T. Triffet, Testimony in the U.S. Congressional Hearings, Special Subcommittee on Radiation, Joint Committee on Atomic Energy, June 1959, "Biological and Environmental Effects of Nuclear War"
Na-24 effect
Data points are NaI (Tl) gamma spectrometry
Unfractionated U-235, thermalized neutrons (Dr C. F. Miller, USNRDL-TR-247, 1958)
95 km downwind (Triffet)
12.6 km downwind (Triffet)
Np-239 effect
(all bombs with U-238 tamper)
Np-239 + U-237
(H-bombs with U-238 fusion charge pusher)
MeV/PHOTON
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1
2
5
10
20
50
100
200
500
1,000
2,000
5,000
10,000
TIME (hr)



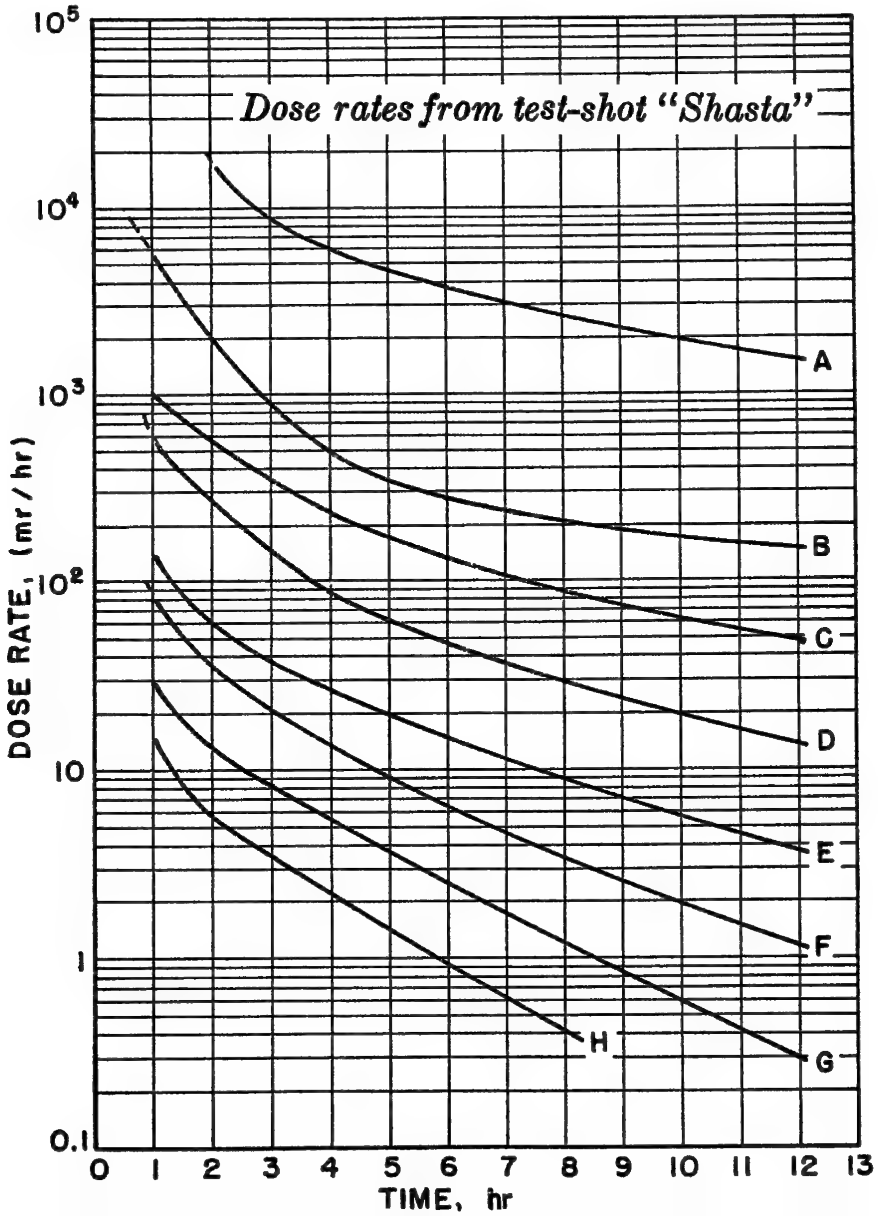
PENETRATION OF UNFRACTIONATED U-235 FISSION PRODUCT GAMMA DOSE RATE IN CONCRETE
Source: L. K. Donovan and A. B. Chilton, "Dose Attenuation Factors for Concrete Slab Shields Covered with Fallout, as a Function of Time after Fission", U.S. Naval Civil Engineering Lab, report R-137, 1961
(Uses spectra published by A. T. Nelms and J. W. Cooper in Health Physics, v1, 1959, pp427-41.)
CHILTON & SAUNDERS (1.0 MeV)
1.12 HRS
2.11 DAYS
23.8 HRS
4.57 DAYS
208 DAYS
ATTENUATION FACTOR
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
0.5
1.0
1.5
2.0
2.5
3.0
THICKNESS OF CONCRETE (feet)


PENETRATION, FEET OF AIR
0
10
20
30
40
CONTAMINATED FLAT PLANE SOURCE
1 HOUR SPECTRUM
1 DAY SPECTRUM
POINT PARTICLE SOURCE, 1 HOUR SPECTRUM
POINT PARTICLE SOURCE, 1 DAY SPECTRUM
FRACTION OF BETA RADIATION ENERGY DEPOSITED
1.0
0.8
0.6
0.4
0.2
0
Source: A. E. Boyd and E. E. Morris, Health Physics, v2 (1960), pp321-5
(Assumes fractionated U-235 fission products, with some volatile nuclides removed)
0
0.4
0.8
1.2
1.6
PENETRATION, g/cm2

F. Titus, Penetration in concrete of gamma radiation from fallout, NBS Report 6143, (Sept. 4, 1958), AEC Report ITR-1477 (Oct. 22, 1957).



The lead shield prevents fallout material from settling directly on detector "A," while at the same time shielding against the intercepted material



MEAN FALLOUT GAMMA ENERGY FOR LAND BURSTS ZUNI AND TEWA AND AIR BURST CHEROKEE
Terry Triffet and Philip D. LaRiviere, *Characterization of Fallout*, WT 1317 (1961), Table B.21

Test	Mt	Fission	Sample	2 days	3 days	4 days	7 days	10 days	14 days
Aircraft-collected unfractionated cloud samples (no depletion of volatile fission products):									
*Navajo**	4.50	5%	Cloud	0.57	0.48	0.45	0.44	0.53	0.60
Zuni	3.53	15%	Cloud	0.48	0.41	0.42	0.43	0.49	
Tewa	5.01	87%	Cloud		0.40	0.38	0.37	0.46	0.49
*Flathead**	0.365	73%	Cloud			0.34			0.54
Cherokee	3.75	50%	Cloud	0.29	0.30	0.31	0.34	0.42	0.49
*Sea water burst fallout is similar to cloud sample (100 °C droplet condensation prevents fractionation).									
Deposited fractionated land surface burst close-in fallout samples (depletion of volatile fission products):									
Tewa	5.01	87%	YFNB13E56					0.27	0.30
Zuni	3.53	15%	How F-61					0.21	

- Laboratory instrument measurements (ignores degradation due to air scatter of gamma rays). The "clean bombs" *Navajo* and *Zuni* cloud samples include high-energy gamma from sodium-24 (15 hours half life) due to neutron capture by sea salt (NaCl). Low-energy gammas, from Np-239 and U-237 due to neutron capture in U-238, contribute a high proportion of fallout radiation at 4-14 days. Fractionation depletes volatile chains, not Np-239 and U-237, so the mean energy is reduced further.

Spectrum of fission product gamma rays from the thermonuclear neutron fission of U-238 as a function of the degree of fractionation for two different times after detonation (Glenn R. Crocker, *Radiation Properties of Fractionated Fallout; Predictions of Activities, Exposure Rates and Gamma Spectra for Selected Situations,* U.S. Naval Radiological Defense Laboratory, USNRDL-TR-68-134, 27 June 1968, 287 pp.)

Gamma ray energy, MeV	Gamma ray spectrum at 1 hour after burst				Gamma ray spectrum at 1 week after burst			
	Sr-89 abundance (relative to unfractionated fallout)				Sr-89 abundance (relative to unfractionated fallout)			
	10% $R_{89,95} = 0.1$	50% $R_{89,95} = 0.5$	100% $R_{89,95} = 1$*	200% $R_{89,95} = 2$	10% $R_{89,95} = 0.1$	50% $R_{89,95} = 0.5$	100% $R_{89,95} = 1$*	200% $R_{89,95} = 2$
0-0.5	0.396	0.354	0.350	0.304	0.695	0.662	0.678	0.637
0.5-1	0.385	0.379	0.363	0.357	0.262	0.270	0.245	0.265
1-1.5	0.1605	0.1863	0.1914	0.232	0.01339	0.01358	0.01218	0.01273
1.5-2	0.0327	0.0466	0.0558	0.0596	0.0287	0.0519	0.0591	0.0790
2-2.5	0.01628	0.0203	0.0279	0.0290	0.001114	0.001313	0.001268	0.001445
2.5-3	0.00429	0.00717	0.01192	0.01305	0.001372	0.00253	0.00291	0.00388
3-3.5	0.00340	0.00301	0.00267	0.00273	0.0000260	0.0000490	0.0000564	0.0000760
3.5-4	0.001425	0.001187	0.001705	0.00214	0	0	0	0
Total:	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Relative gamma activity	0.547	0.756	1*	1.25	0.563	0.768	1*	1.12
Mean energy, MeV	0.710	0.767	0.807	0.856	0.444	0.486	0.483	0.526

*Unfractionated ($R_{89,95} = 1$) fission product composition relative gamma activity is normalized to 1 unit/second. The presence of neutron induced activities in U-238 like Np-239, U-240, and U-237 due to non-fission capture is not included, and would further soften the fractionated fallout spectra, since they emit low energy gamma rays.

Measured capture to fission ratios in nuclear tests*

				Number of neutron capture atoms per fission		
Test shot	*Weapon design*	*Yield*	*Fission %*	*U-239 & Np-239*	*U-237*	*U-240 & Np-240*
Jangle-Sugar	U238 reflector	1.2 kt	100	0.59		
Jangle-Uncle	U238 reflector	1.2 kt	100	0.59		
Castle-Bravo	U238 pusher	14.8 Mt	68	0.56	0.10	0.14
Castle-Romeo	U238 pusher	11 Mt	64	0.66	0.10	0.23
Castle-Koon	U238 pusher	110 kt	91	0.72	0.10	
Castle-Union	U238 pusher	6.9 Mt	72	0.44	0.20	0.07
Redwing-Zuni		3.53 Mt	15	0.31	0.20	0.005
Redwing-Tewa		5.01 Mt	87	0.36	0.20	0.09
Diablo	U238 in core**	18 kt	100	0.10		
Shasta	U238 in core**	16 kt	100	0.10		
Coulomb C	U238 in core**	0.6 kt	100	0.03		

* Data is derived from all analyses of aircraft cloud fallout samples and deposited fallout samples in Dr Carl F. Miller, U.S. Naval Radiological Defense Laboratory, report USNRDL-466 (1961), Table 6.
**In these Plumbbob weapon tests, there was no U238 reflector and the only U238 in the bomb was that contained in the fissile core as an impurity.

Measured relationship between the fusion yield of the nuclear explosive and the quantity of neutron-induced activities in the fallout*

Test		*Redwing-Navajo*	*Redwing-Zuni*	*Redwing-Tewa*	
Design		Lead pusher	Lead pusher	U-238 pusher	
Total yield		4.5 Mt	3.53 Mt	5.01 Mt	
% Fission		5	15	87	
% Fusion		95	85	13	
Nuclide	*Half life*	*Abundance of nuclide in bomb fallout, atoms per bomb fission*			*R1***
Na-24	15 hours	0.0314	0.0109	0.00284	1284.7
Cr-51	27.2 days	0.0120	0.0017	0.00030	0.280
Mn-54	304 days	0.10	0.011	0.00053	0.614
Mn-56	2.58 hours	0.094		0.00053	2668
Fe-59	45.2 days	0.0033	0.00041	0.00017	6.19
Co-57	272 days	0.00224	0.0031	0.00018	0.113
Co-58	71 days	0.00193	0.0036	0.00029	3.11
Co-60	5.27 years	0.0087	0.00264	0.00081	0.299
Cu-64	12.8 hours	0.0278	0.0090	0.0023	89.5
Sb-122	2.75 days		0.219***		38.4
Sb-124	60 days		0.073***		6.92
Ta-180	8.15 hours	0.038	0.0411		35.9
Ta-182	114 days	0.038	0.0326	0.01	2.67
Pb-203	52 hours	0.0993	0.050	0.000018	26.0
U-237	6.75 days		0.20	0.20	6.50
U-239	23.5 minutes	0.085	0.31	0.36	173
Np-239	56.4 hours	0.085	0.31	0.36	14.9*+*
U-240	14.1 hours		0.005	0.09	0 (no gamma rays)
Np-240	7.3 minutes		0.005	0.09	150

*Dr Terry Triffet and Philip D. LaRiviere, "Characterization of Fallout, Operation Redwing, Project 2.63," U.S. Naval Radiological Defense Laboratory, 1961, report WT-1317, Table B.22. Data on U-238 capture nuclides is from USNRDL-466, Table 6, in combination with WT-1315, Table 4.1.

**Triffet's 1961 values for the gamma dose rate at 1 hour after burst at 3 ft above an infinite, smooth, uniformly contaminated plane, using an ideal measuring instrument with no shielding from the person holding the instrument, from 1 atom/fission of induced activity, (R/hr)/(fission kt/square stat mile).

***The Zuni bomb contained a lot of antimony (Sb), which melts at 903.7K and boils at 1650K. The abundances of Sb-122 and Sb-124 given in the table are for unfractionated cloud samples; because of the low boiling point of antimony, it was fractionated in close-in fallout, so the abundances of both Sb-122 and Sb-124 in the Zuni fallout at Bikini Lagoon were 8.7 times lower than the unfractionated cloud fallout.

*+*Note that Np-239 at 1 hour after burst is still forming as the decay product of U-239.

Zuni* fallout gamma ray spectrum measured at 10 days after detonation, 13 miles downwind (sample How F-61 GA)

Gamma ray energy (MeV)	% of gamma rays emitted by fallout sample
0.060	15.5
0.105	38.8
0.220	19.4
0.280	9.3
0.330	3.8
0.500	3.9
0.650	3.1
0.750	6.2
Mean energy	**0.218 MeV**

*W. E. Thompson, *Spectrometric Analysis of Gamma Radiation from Fallout from Operation Redwing,* U. S. Naval Radiological Defense Laboratory technical report USNRDL-TR-146, 29 April 1957, Tables 1 and 2. Note that this is the gamma ray spectrum actually measured for a fallout sample placed near the scintillation crystal of a gamma ray spectrometer, so it does not include the further reduction in gamma ray energy that occurs from Compton scattering in the atmosphere.

Krypton-89, krypton-90, and xenon-140, which are present during the formation of the fireball and are precursors for strontium-89, strontium-90, and barium-140, have very little tendency to be incorporated uniformly in the particles during the early stage of formation. These noble gases, when associated with a particle, are deposited unevenly on the surface layers and distributed along with relatively large deposits of inactive debris which were drawn toward the fireball too late to form fused radioactive particles.

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Both strontium-89 and strontium-90 are examples of radioisotopes having gaseous precursors and are thus subject to a high degree of fractionation.

$$\text{Krypton-89} \xrightarrow[\text{2.6 min}]{\beta^-} \text{Rubidium-89} \xrightarrow[\text{15 min}]{\beta^-} \text{Strontium-89}$$

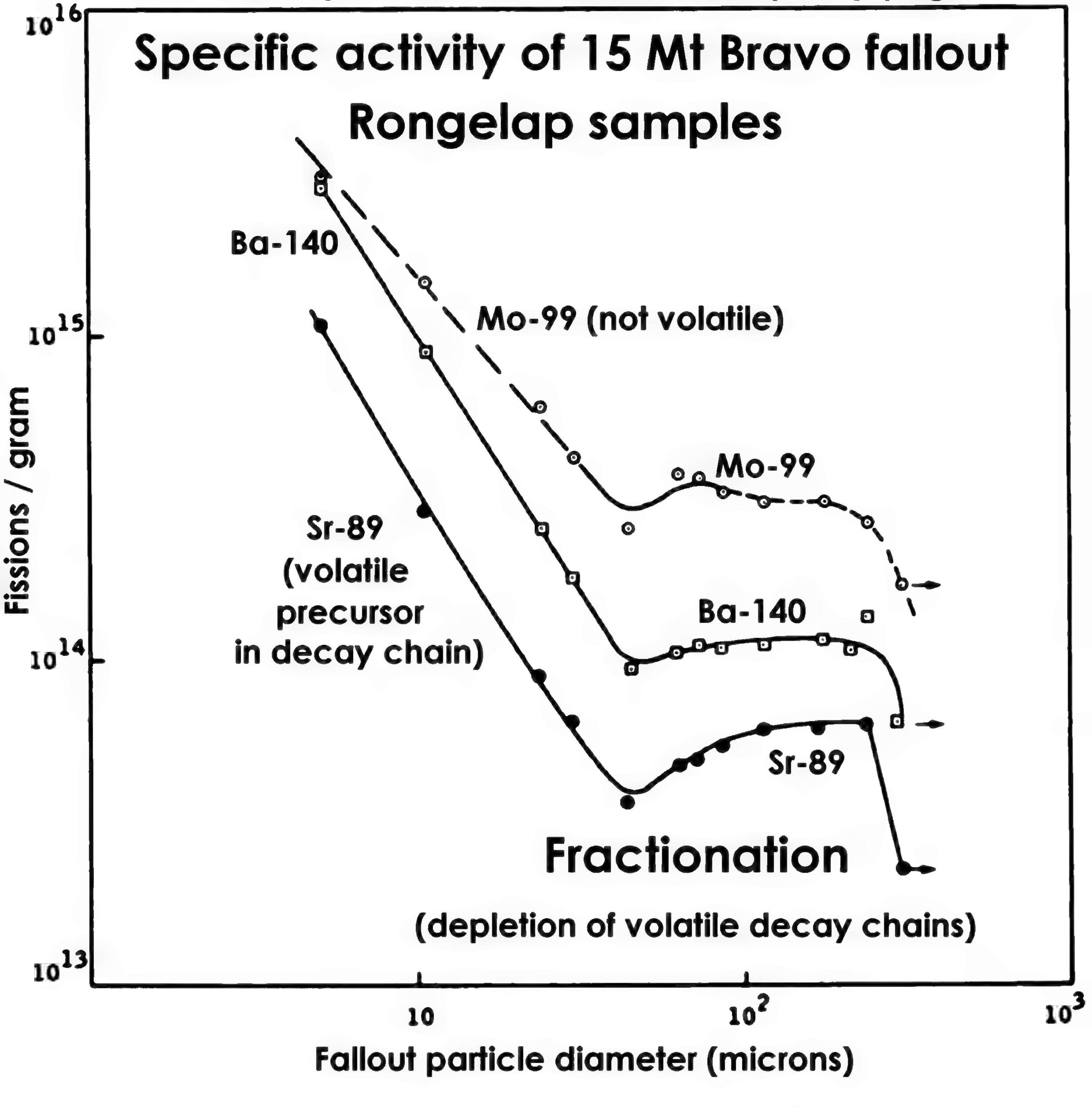
$$\text{Krypton-90} \xrightarrow[\text{33 sec}]{\beta^-} \text{Rubidium-90} \xrightarrow[\text{V.Short}]{\beta^-} \text{Strontium-90}$$

31

As expected from the earlier discussion, strontium exhibits very definite fractionation. On one series of air samples collected at 40,000 feet at Operation CASTLE after the Bravo shot, the R value for strontium-89 was 0.35. For a fall-out sample collected on land at approximately 80 miles from the burst point, the R value for strontium-89 was 0.14. The R value for strontium-90 using the same fall-out sample was 0.29.

33

Radioactivity in the Marine Environment (1971), page 13.



Coral Island Surface Explosion (Equivalent fissions $\times 10^{-14}$ per gram)

Morgenthau *et al.* (1960). **Weapon Test report WT-1319, "Operation Redwing: Land Fallout Studies"**

REDWING-LACROSSE Normalized to 100% fission yield

0.04 Mt
Shot Atoll

Platform on reef off Runit Island, Enewetak

$D_g(\mu)$	Chain 99 (^{99}Mo)	Chain 89 (^{89}Sr)	Chain 140 (^{140}Ba)
57	2.5	0.063	0.25
88	4.0	0.074	0.28
125	4.7	0.082	0.30
177	5.7	0.062	0.23
297	4.5	0.044	0.18
594	1.6	0.063	0.24

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RADIOCHEMICAL ANALYSIS OF INDIVIDUAL FALLOUT PARTICLES

Research and Development Technical Report USNRDL-TR-386

17 September 1958

by

J. L. Mackin
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D. Sam

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO 24 · CALIFORNIA

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TABLE 2 (ZUNI, barge YFNB-29; see Table B8 in WT-1317)

Weight, Activity, and Fission Values for the Sized Fractions From the WHIM Sample (YFNB29, 17 km from ZUNI)

Size Range (μ)	Weight: Grams	Weight: Percent of Total	Fissions: Percent of Total	Fissions: Total (10^{14})	Fissions: Per Gram (10^{14})
>1000	37.70	41.8	15.8	21.	0.56
500-1000	41.91	46.4	46.0	60.	1.4
250- 500	4.97	5.5	19.8	26.	5.2
100- 250	3.51	3.9	10.7	14.	4.0
50- 100	0.80	0.9	2.3	3.0	3.8
<50	1.38	1.5	5.4	7.1	5.1
Total	90.27			131.	1.5

TABLE 4 (ZUNI: BIKINI/HOW ISLAND, YFNB29, YAG40; TABLE 3.9 IN WT-1317)

Mean Values for Several Quantities, for Altered and Unaltered Particles

Quantity	Melted coral sand, Altered: No. of Samples	Altered: Value	Unmelted coral sand, Unaltered: No. of Samples	Unaltered: Value
fiss/gm($x10^{14}$)	6	3.8 ± 3.1	9	0.090 ± 0.12
Ba^{140}-R value	5	0.090 ± 0.068	8	2.1 ± 1.2
Sr^{89}-R value	7	0.018 ± 0.010	10	0.65 ± 0.17

The data of Table 4 show that the value of fissions/gram was much larger in the altered particles than in the unaltered particles. The R value data indicates that the altered particles were markedly depleted in Ba^{140}-La^{140}, whereas the unaltered particles were enriched in Ba^{140}-La^{140}

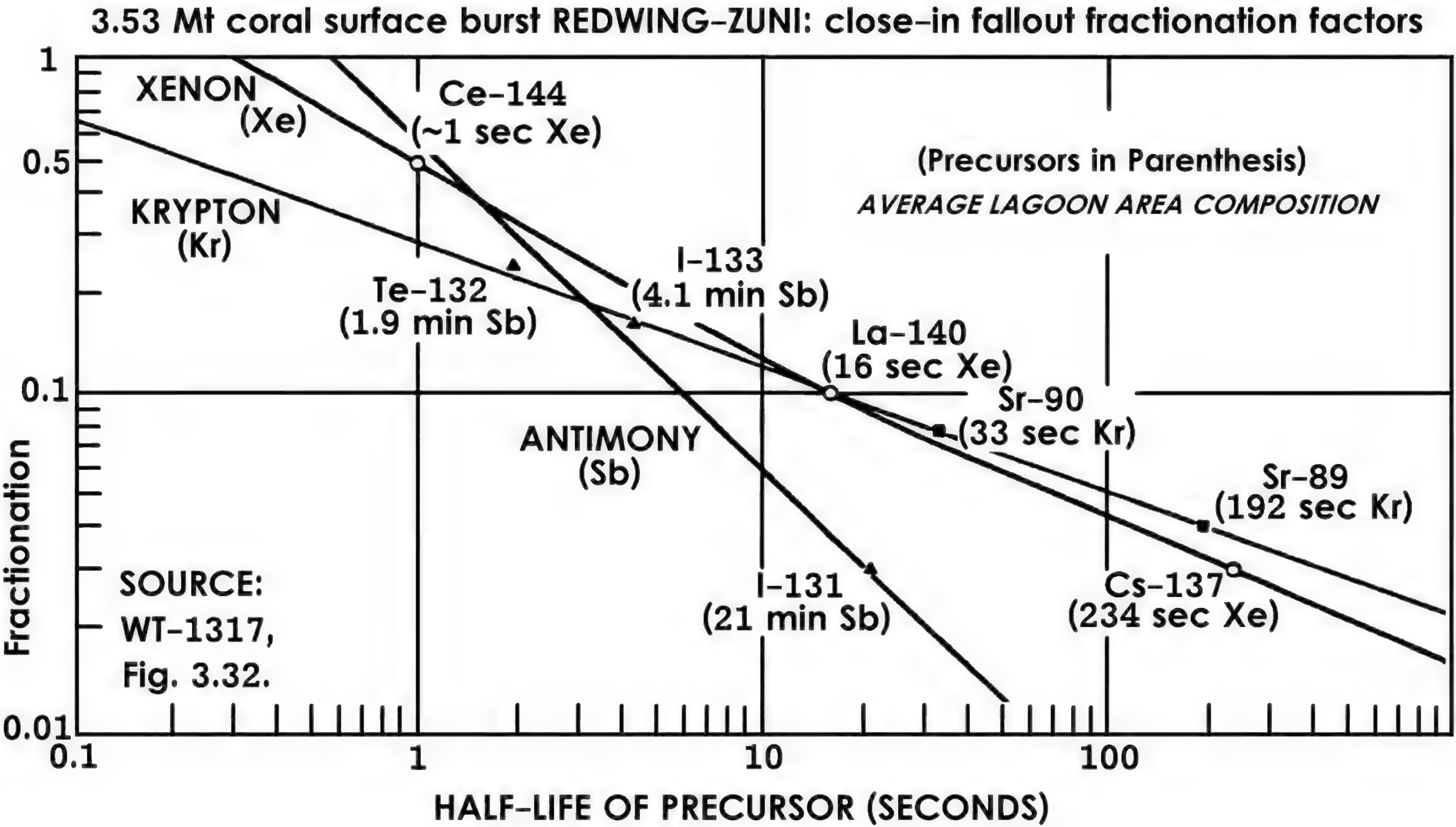
R values

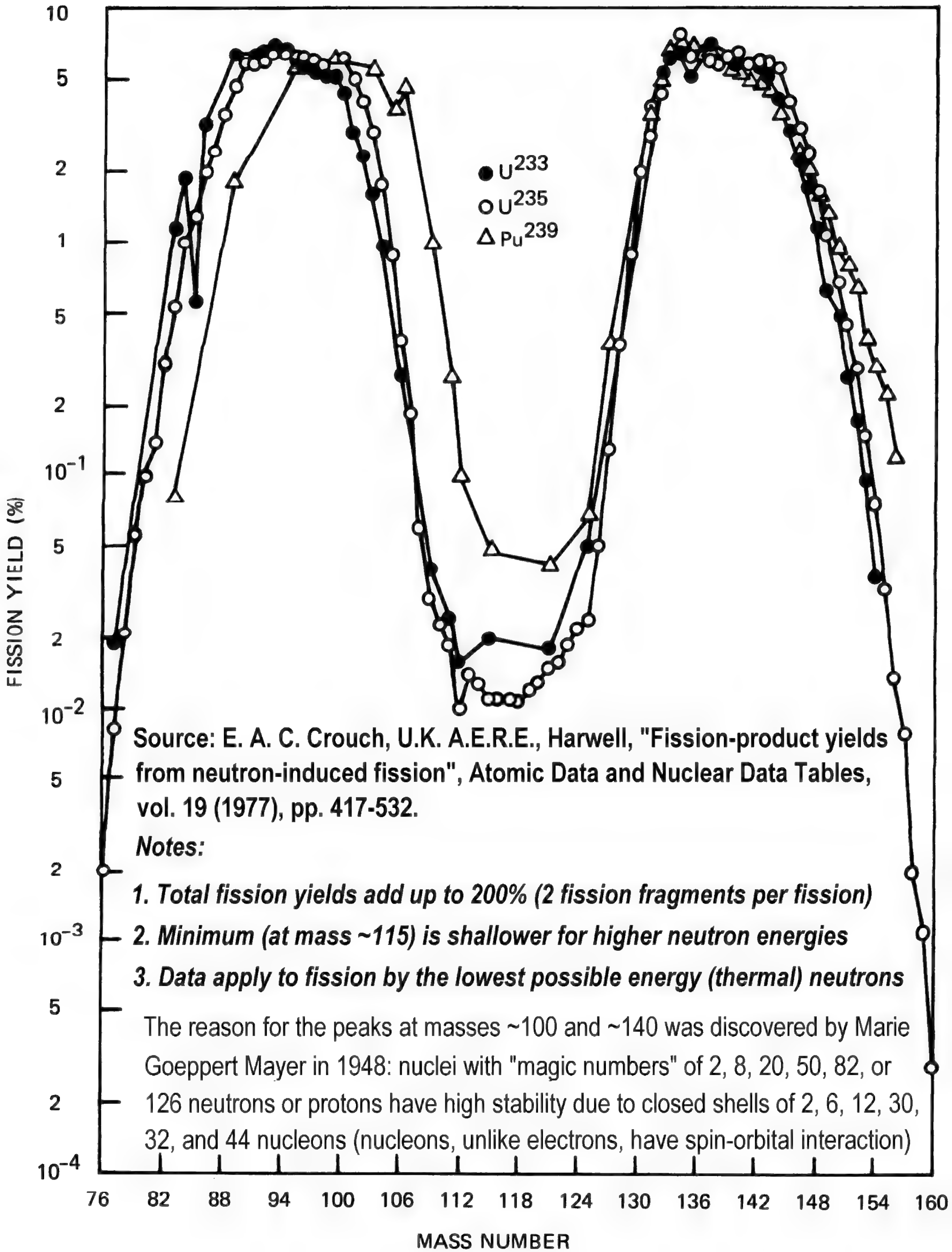
With respect to fractionation of radionuclides it has long been accepted that the mass 89 and mass 140 chains which exist for long time periods as noble gases, halogens and alkali metals* would condense late and therefore disproportionate with respect to less volatile elements. On the basis of long-lived gaseous precursors it would be predicted that the altered or melted particles would exhibit low R values for both chains, with the 89 smaller of the two. This was verified by the mean R values given in Table 4, which were 0.090 and 0.018 for the 140 and 89 chains, respectively. The corresponding values for the unaltered particles of 2.1 and 0.65 indicate that this latter class of particles may be important as a scavenger of these nuclides.

It is also of interest to compare R values obtained in this study with values obtained on gross fallout samples. The latter data gave Ba^{140} R values and Sr^{89} R values of 0.10 and 0.04 respectively** in the lagoon samples. The low R values for the gross sample from the lagoon area are similar to R values obtained with altered particles and suggests a lagoon fallout composed primarily of altered particles. This suggestion is supported by the WHIM sample fission/gram data (described above).

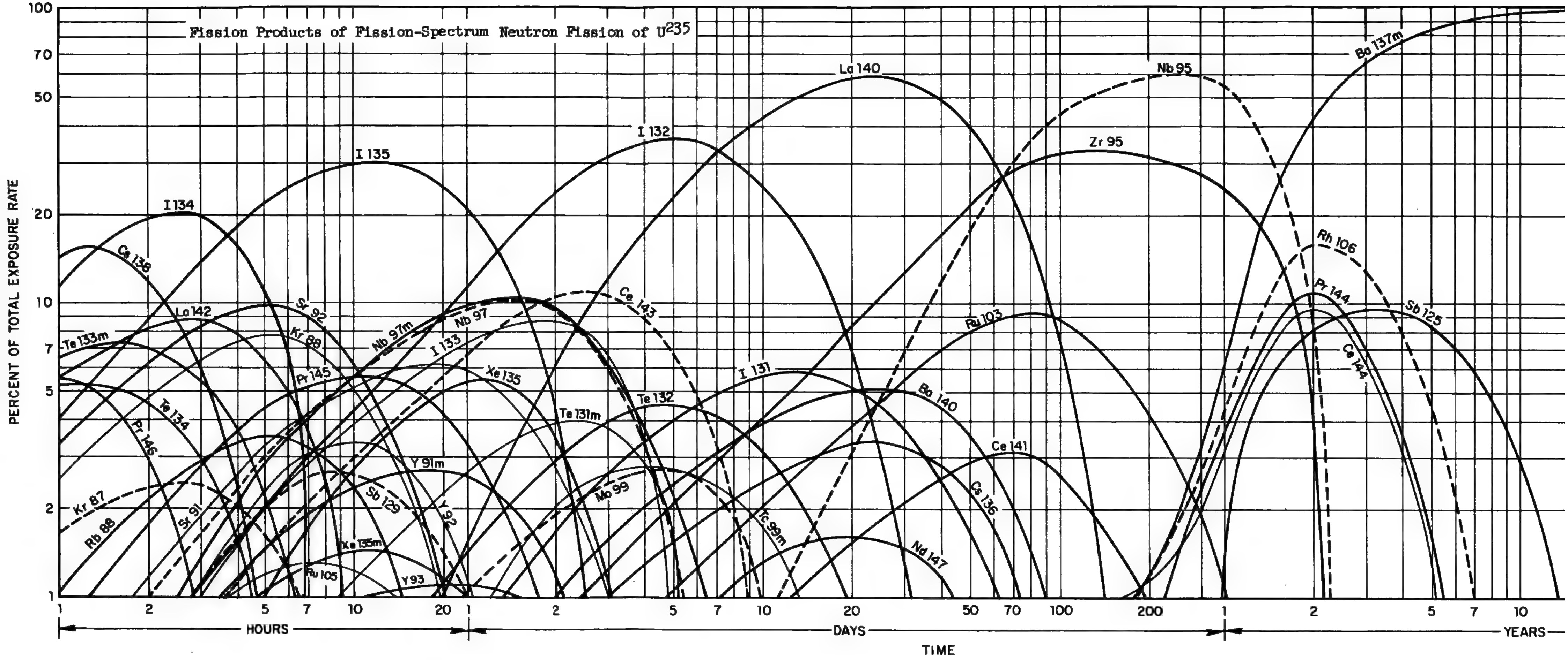
* Ba^{140} is formed by the decay of the radioelements Xe^{140} (16-sec half-life) and Cs^{140} (66-sec half-life); Sr^{89} is formed by the decay of the radioelements Kr^{89} (3.16-min half-life) and Rb^{89} (15.4-min half-life).

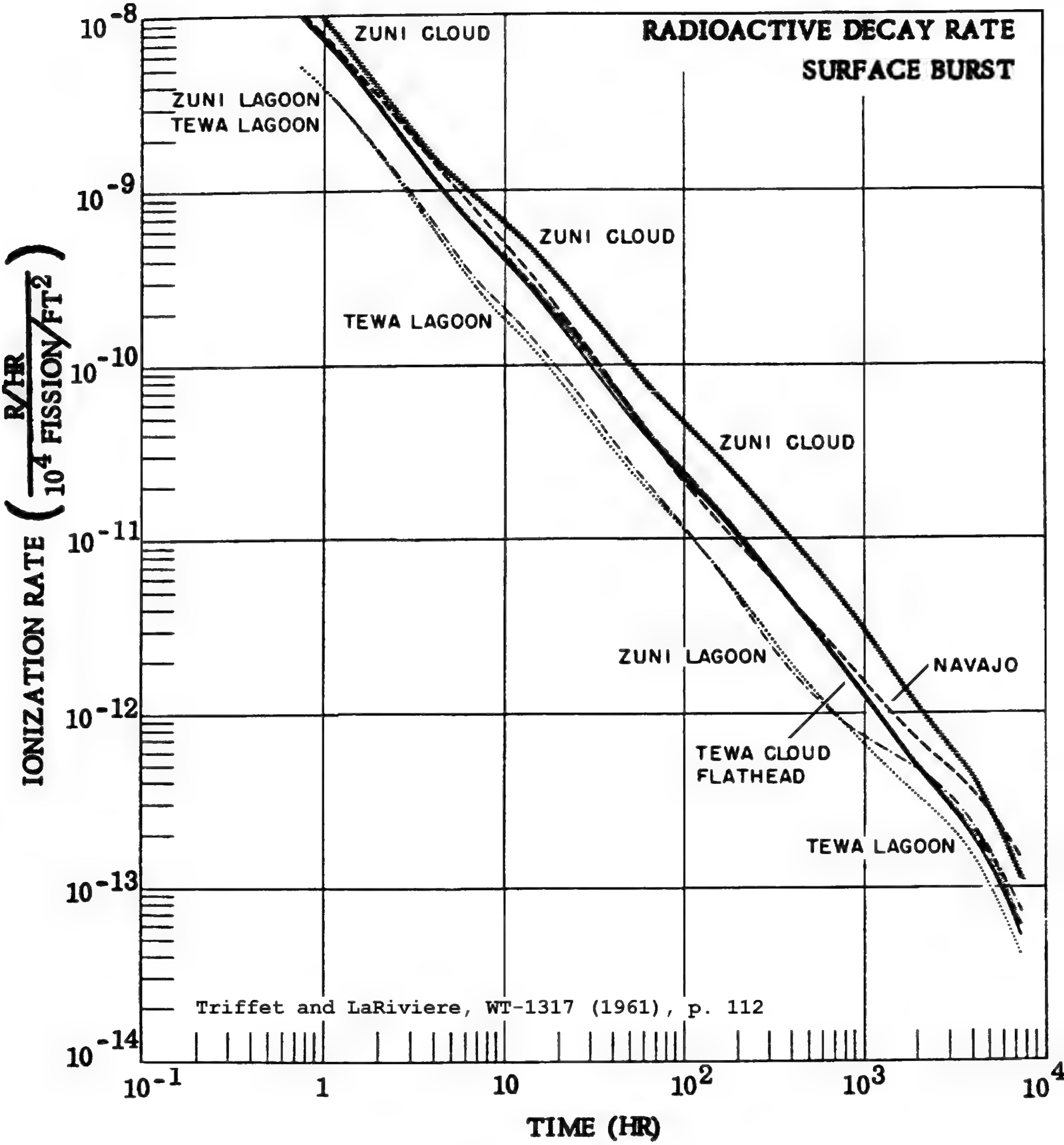
** P.D. LaRiviere, USNRDL, personal communication.


3.53 Mt coral surface burst REDWING–ZUNI: close–in fallout fractionation factors
XENON
(Xe)
KRYPTON
(Kr)
Ce–144
(~1 sec Xe)
Te–132
(1.9 min Sb)
I–133
(4.1 min Sb)
(Precursors in Parenthesis)
AVERAGE LAGOON AREA COMPOSITION
La–140
(16 sec Xe)
Sr–90
(33 sec Kr)
Sr–89
(192 sec Kr)
ANTIMONY
(Sb)
I–131
(21 min Sb)
Cs–137
(234 sec Xe)
SOURCE:
WT–1317,
Fig. 3.32.
Fractionation
1
0.5
0.1
0.01
0.1
1
10
100
HALF–LIFE OF PRECURSOR (SECONDS)


FISSION YIELD (%)
MASS NUMBER
10
5
2
1
5
2
10^{-1}
5
2
10^{-2}
5
2
10^{-3}
5
2
10^{-4}
76
82
88
94
100
106
112
118
124
130
136
142
148
154
160
U^{233}
U^{235}
Pu^{239}
Source: E. A. C. Crouch, U.K. A.E.R.E., Harwell, "Fission-product yields from neutron-induced fission", Atomic Data and Nuclear Data Tables, vol. 19 (1977), pp. 417-532.
Notes:
1. Total fission yields add up to 200% (2 fission fragments per fission)
2. Minimum (at mass ~115) is shallower for higher neutron energies
3. Data apply to fission by the lowest possible energy (thermal) neutrons
The reason for the peaks at masses ~100 and ~140 was discovered by Marie Goeppert Mayer in 1948: nuclei with "magic numbers" of 2, 8, 20, 50, 82, or 126 neutrons or protons have high stability due to closed shells of 2, 6, 12, 30, 32, and 44 nucleons (nucleons, unlike electrons, have spin-orbital interaction)

Source: USNRDL-TR-1009 (curves for Pu-239, U-233 and U-238 by different neutron energies are very similar)




RADIOACTIVE DECAY RATE
SURFACE BURST
ZUNI CLOUD
ZUNI LAGOON
TEWA LAGOON
ZUNI CLOUD
TEWA LAGOON
ZUNI CLOUD
ZUNI LAGOON
NAVAJO
TEWA CLOUD
FLATHEAD
TEWA LAGOON
Triffet and LaRiviere, WT-1317 (1961), p. 112
IONIZATION RATE $\left(\frac{R/HR}{10^4\ FISSION/FT^2}\right)$
TIME (HR)
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-1}
1
10
10^2
10^3
10^4

43
TIR's indicated, on the average, 0.85 ± 25 percent of the survey meter readings
60
observed/calculated ratio varies from 0.45 at 11.2 hours
to 0.66 from 100 to 200 hours, to 0.56 between 370 and 1,000 hours.

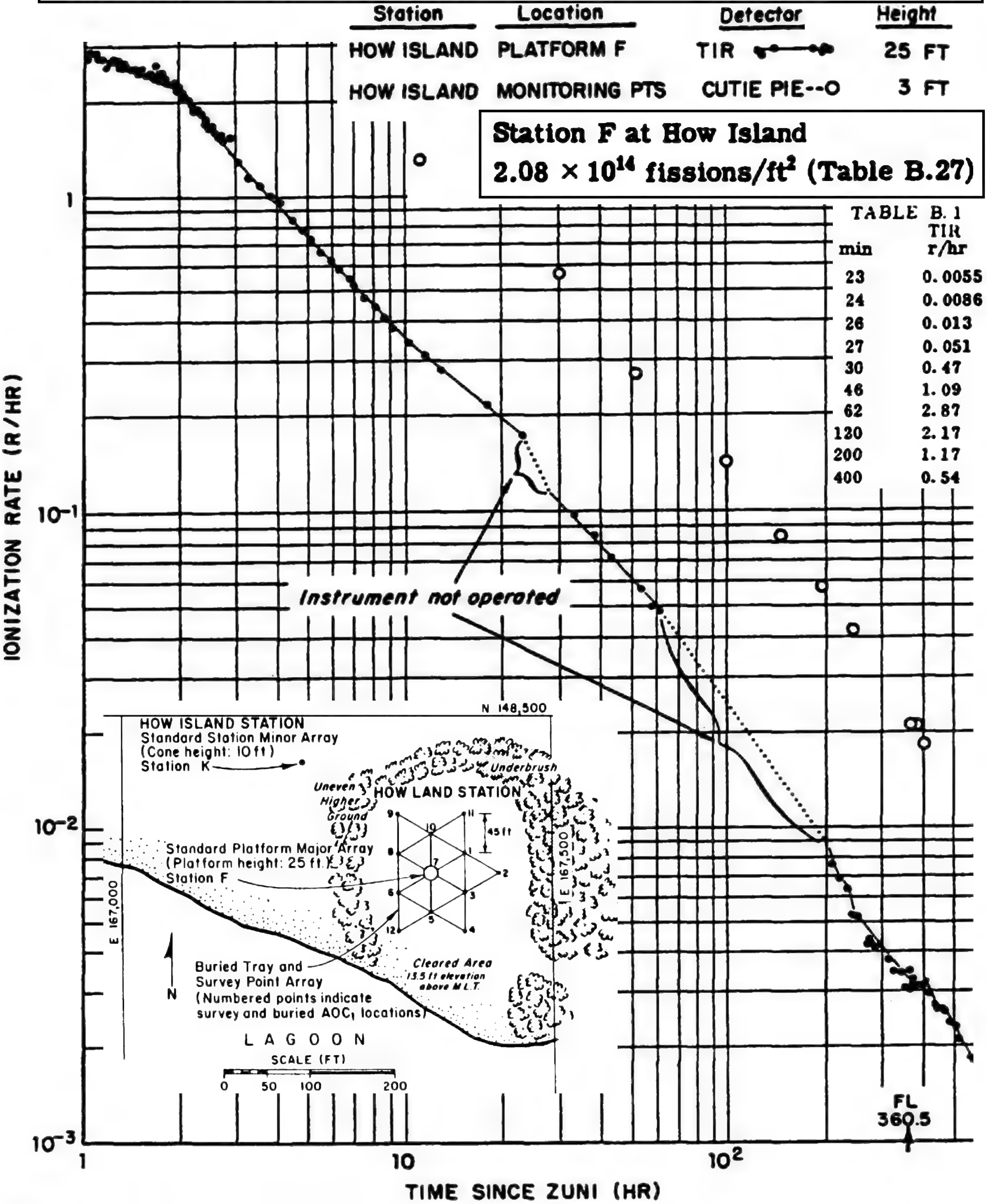


TABLE B.1

min	TIR r/hr
23	0.0055
24	0.0086
26	0.013
27	0.051
30	0.47
46	1.09
62	2.87
120	2.17
200	1.17
400	0.54

Figure B.7 Gamma-ionization-decay rate, Site How.

LAND SURFACE BURST

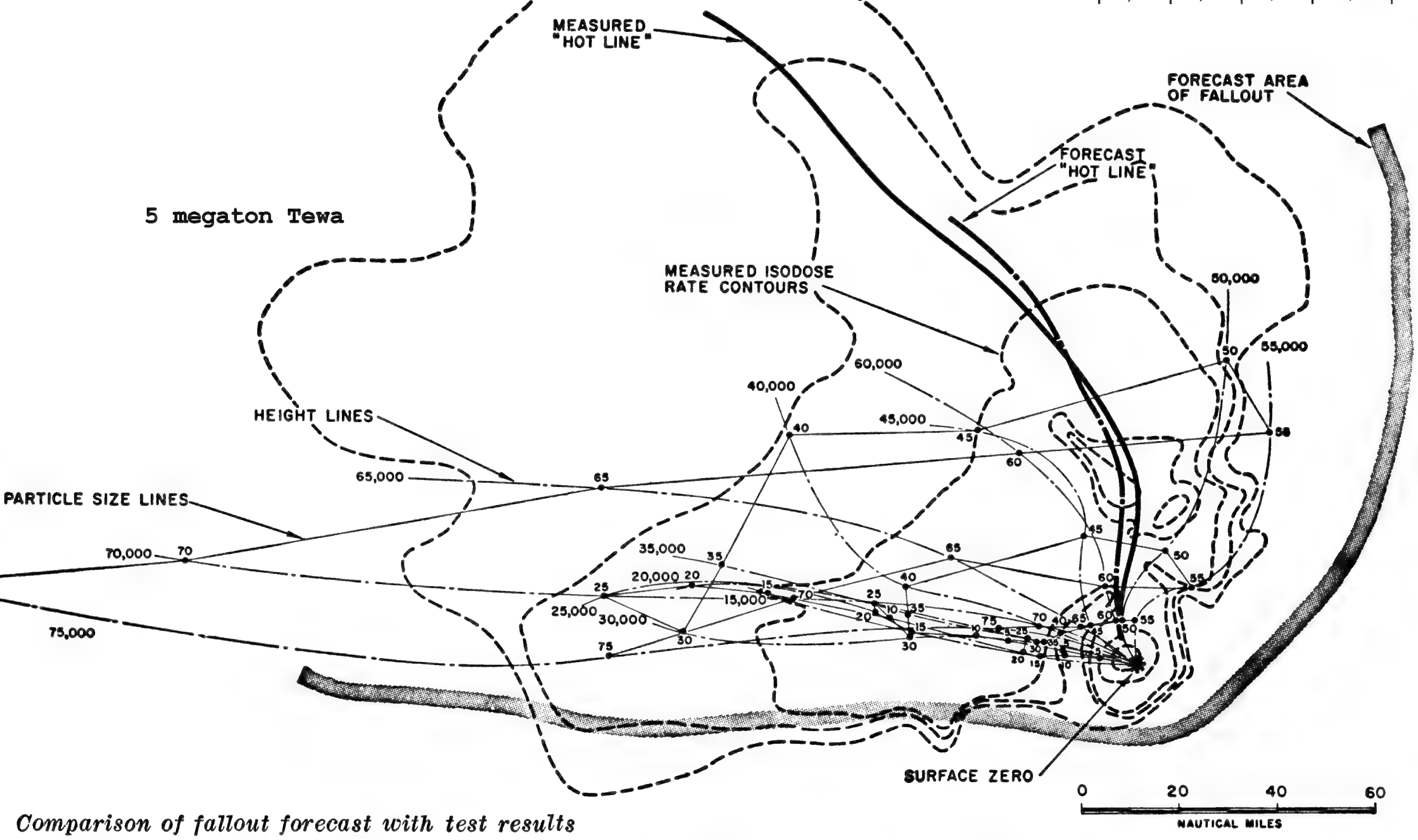
A Fallout Forecasting Technique With Results Obtained at the Eniwetok Proving Ground

E. A. Schuert, USNRDL TR–139, United States Naval Radiological Defense Laboratory, San Francisco, Calif.

2.36 g/cu cm irregular in shape

Falling speeds (feet/hour)

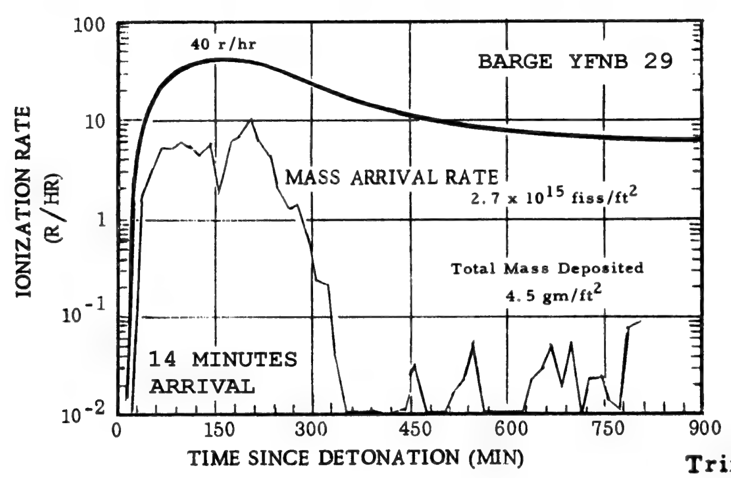
Altitude	75 μ	100 μ	200 μ	350 μ
0	3,060	5,040	11,700	21,600
20	3,360	5,980	14,400	27,100
40	3,870	6,910	18,600	35,300
60	4,200	7,700	24,400	47,200
80	3,910	6,960	27,800	61,900



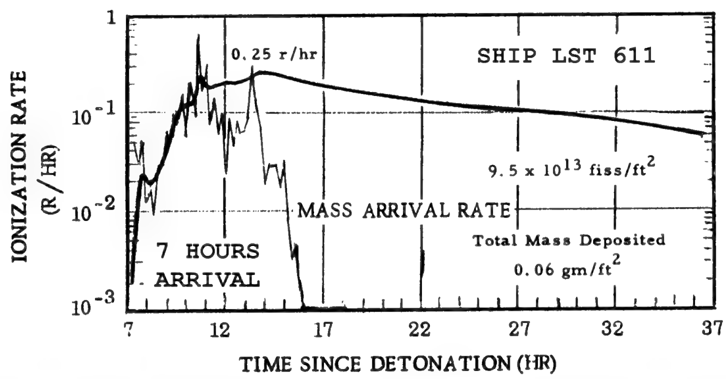
Comparison of fallout forecast with test results

HEIGHT LINE = DESTINATIONS FOR A FIXED HEIGHT OF ORIGIN FOR VARIOUS SIZES
SIZE LINE = DESTINATIONS FOR A FIXED PARTICLE SIZE FROM VARIOUS HEIGHTS
HOT LINE = HEIGHT LINE FROM BASE OF MUSHROOM DISC (MAXIMUM FALLOUT)

5 MT TEWA (87% FISSION), 7.84 STAT. MILES WSW



5 MT TEWA (87% FISSION), 59.3 STAT. MILES NW



Triffet, T. and LaRiviere, P. D.; Characterization of Fallout

WATER SURFACE BURST

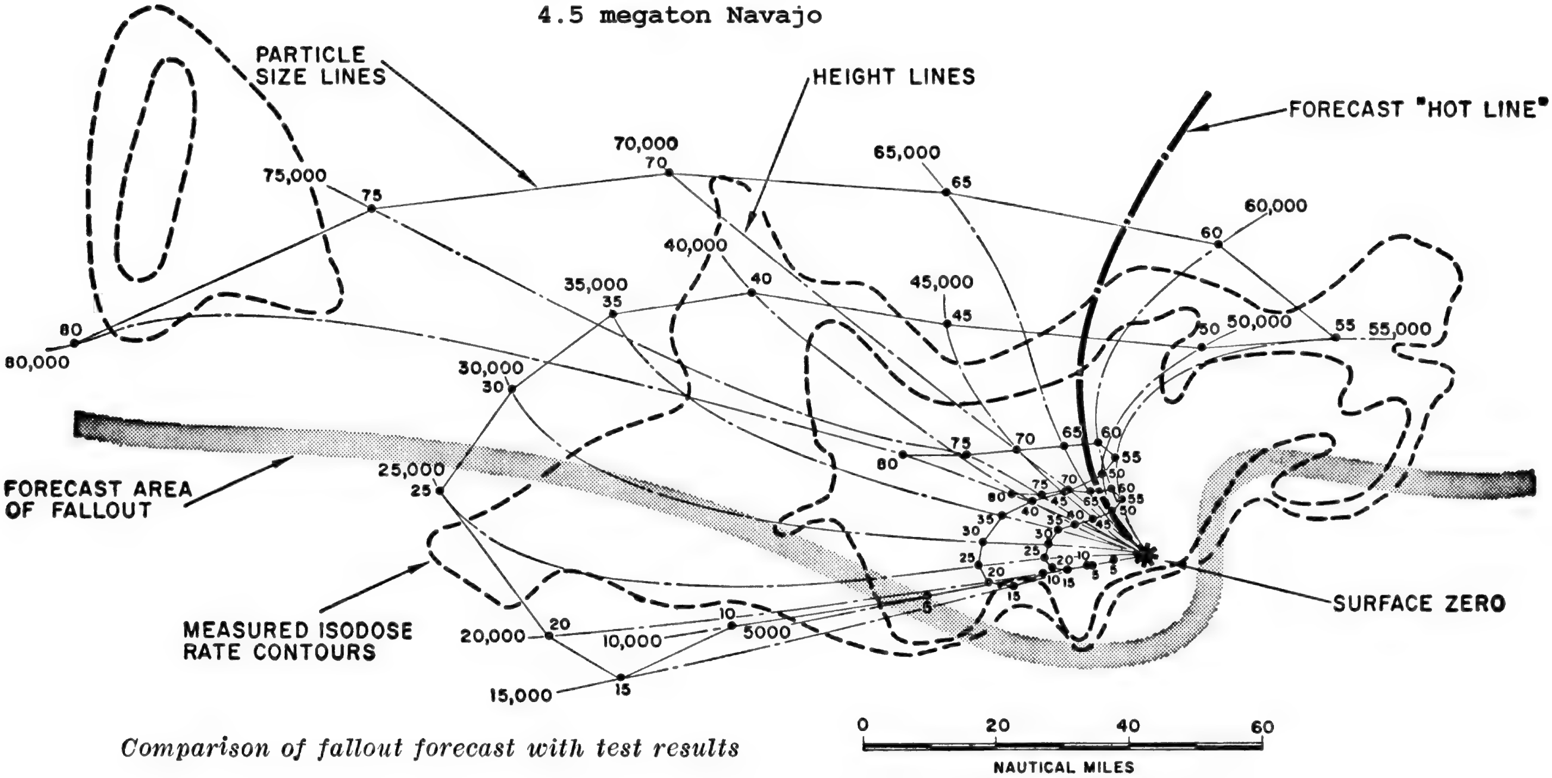
A Fallout Forecasting Technique With Results Obtained at the Eniwetok Proving Ground

E. A. Schuert, USNRDL TR-139, United States Naval Radiological Defense Laboratory, San Francisco, Calif.

Time variation of the winds aloft

In most of the observations made at the Eniwetok Proving Ground, the winds aloft were not in a steady state. Significant changes in the winds aloft were observed in as short a period as 3 hours. This variability was probably due to the fact that proper firing conditions which required winds that would deposit the fallout north of the proving ground, occurred only during an unstable synoptic situation of rather short duration.

4.5 megaton Navajo



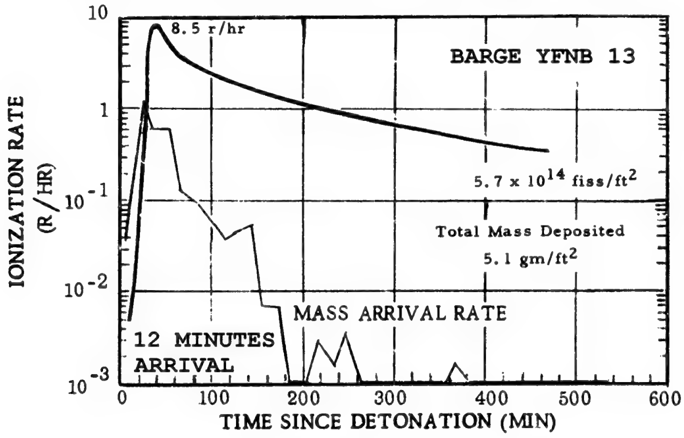
Comparison of fallout forecast with test results

HEIGHT LINE = DESTINATIONS FOR A FIXED HEIGHT OF ORIGIN FOR VARIOUS SIZES

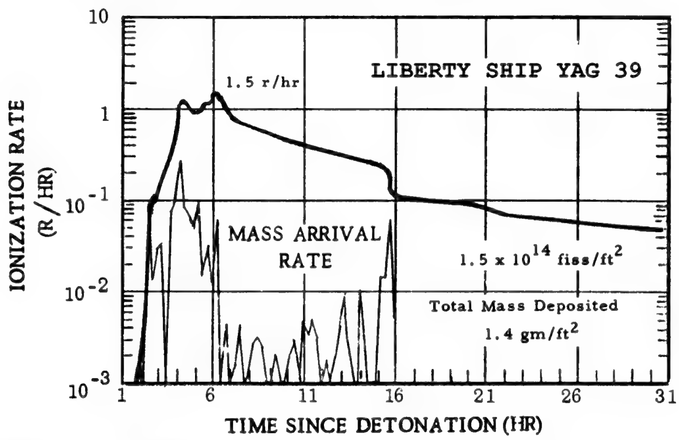
SIZE LINE = DESTINATIONS FOR A FIXED PARTICLE SIZE FROM VARIOUS HEIGHTS

HOT LINE = HEIGHT LINE FROM BASE OF MUSHROOM DISC (MAXIMUM FALLOUT)

4.5 MT NAVAJO (5% FISSION), 7.54 STAT. MILES W

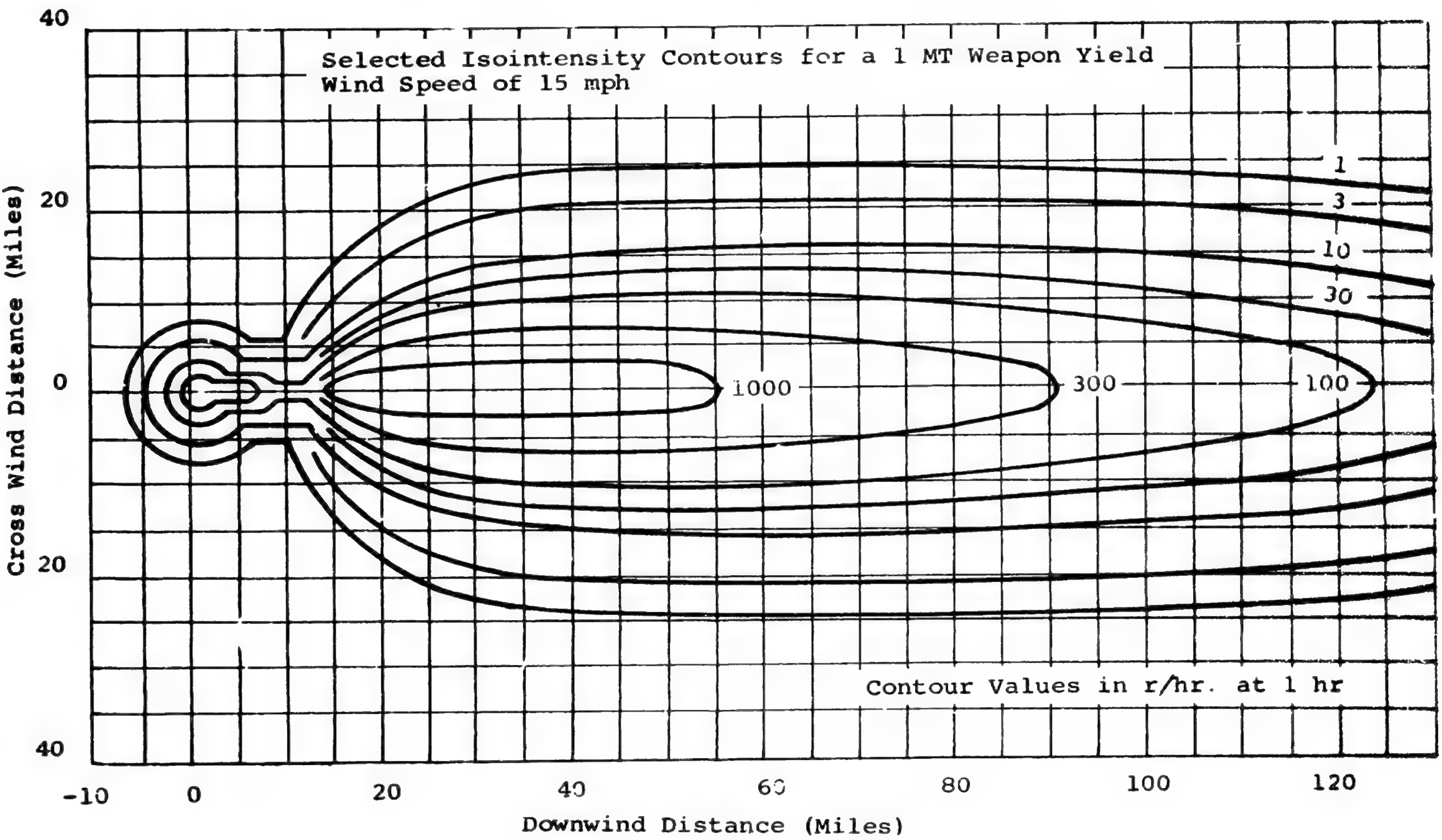


4.5 MT NAVAJO (5% FISSION), 21.0 STAT. MILES N

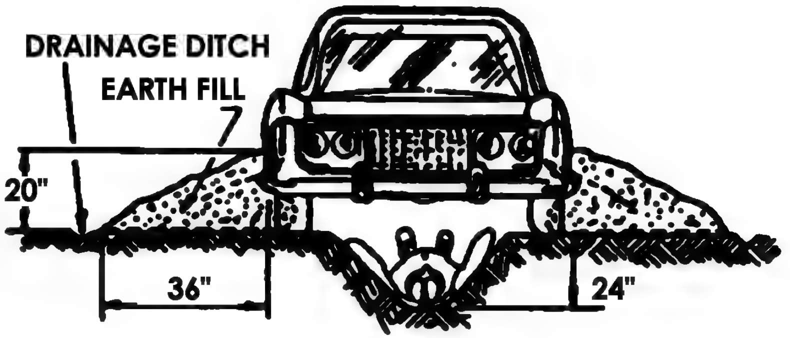


Triffet, T. and LaRiviere, P. D.; Characterization of Fallout, Project 2.63

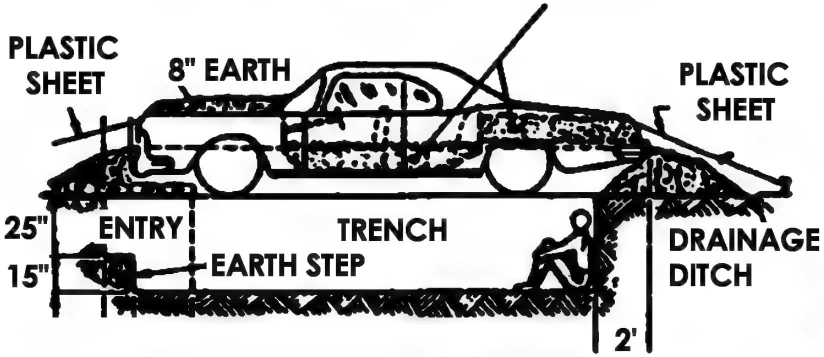
Carl F. Miller, Fallout and Radiological Countermeasures, SRI, 1963



CAR-OVER-TRENCH FALLOUT SHELTER (EXPEDIENT SHELTER HANDBOOK)



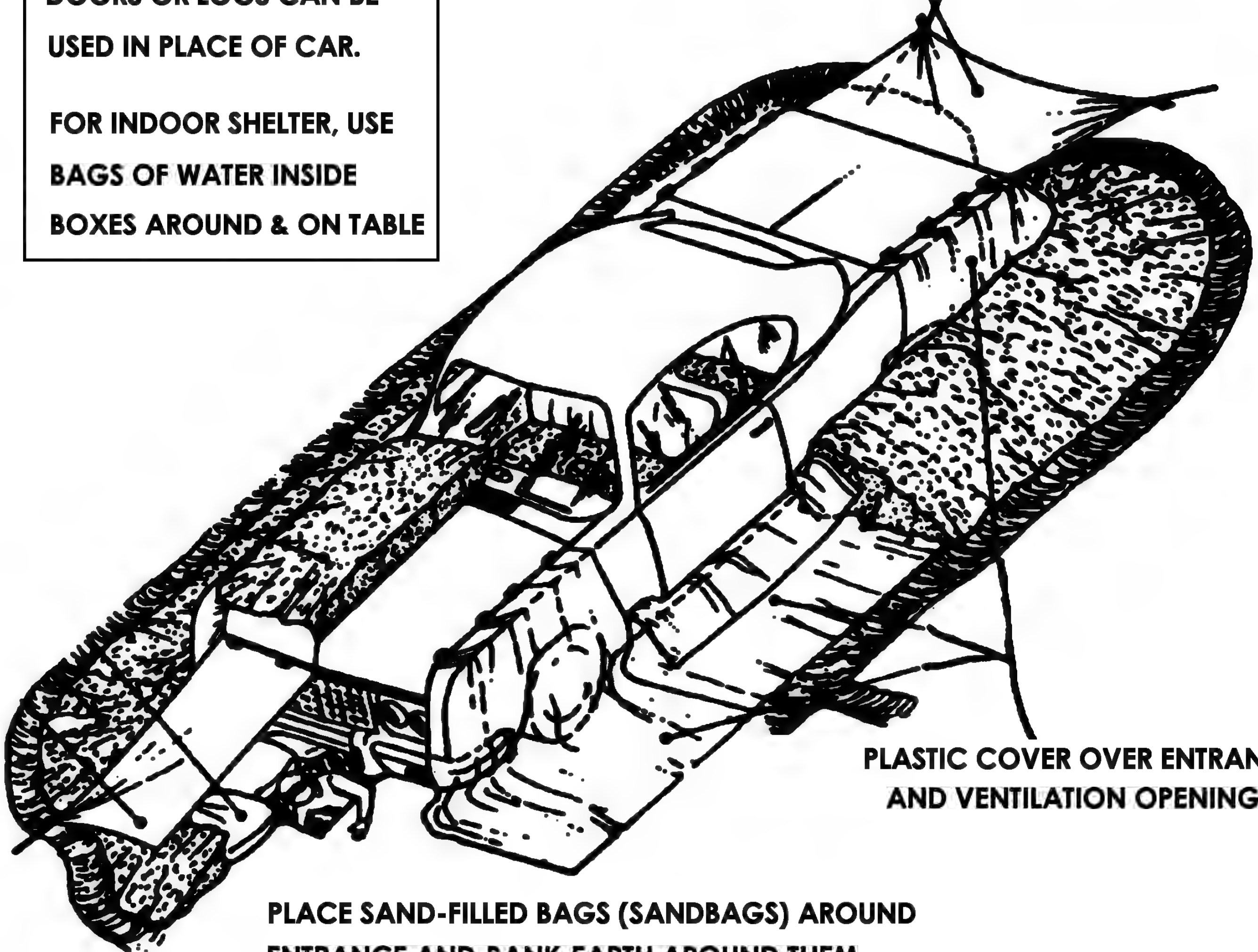
COVER FLOOR AND TRUNK WITH PLASTIC SHEET
PLACE 1 FOOT OF EARTH ON FLOOR AND TRUNK



BANK EXCAVATED EARTH 20 INCHES HIGH AROUND CAR
PLACE 8" OF EARTH ON CAR HOOD
DIG SHALLOW DRAINAGE DITCH AROUND FILL

DOORS OR LOGS CAN BE USED IN PLACE OF CAR.

FOR INDOOR SHELTER, USE BAGS OF WATER INSIDE BOXES AROUND & ON TABLE



PLACE SAND-FILLED BAGS (SANDBAGS) AROUND ENTRANCE AND BANK EARTH AROUND THEM

PERSONAL AND FAMILY SURVIVAL

SM-3-11

"...the history of this planet and particularly the history of the 20th Century is sufficient to remind us of the possibilities of an irrational attack, a miscalculation, and accidental war, or a war of escalation in which the stakes by each side gradually increase to the point of maximum danger which cannot be either foreseen or deterred. It is on this basis that civil defense can be readily justified—as insurance for the civilian population in case of enemy miscalculation. It is insurance we trust will never be needed—but insurance which we would never forgive ourselves for foregoing in the event of catastrophe."

— President Kennedy, in May 1961

Remove doors from their hinges and place them over supports

Drinking-water is required for survival. It is also useful as a shielding material. A collapsible children's swimming pool filled with water and located over the best corner of your basement will help improve the fallout protection. A bathtub, if suitably located, can also be used for this purpose.

DEPARTMENT OF DEFENSE
OFFICE OF CIVIL DEFENSE

LIFE

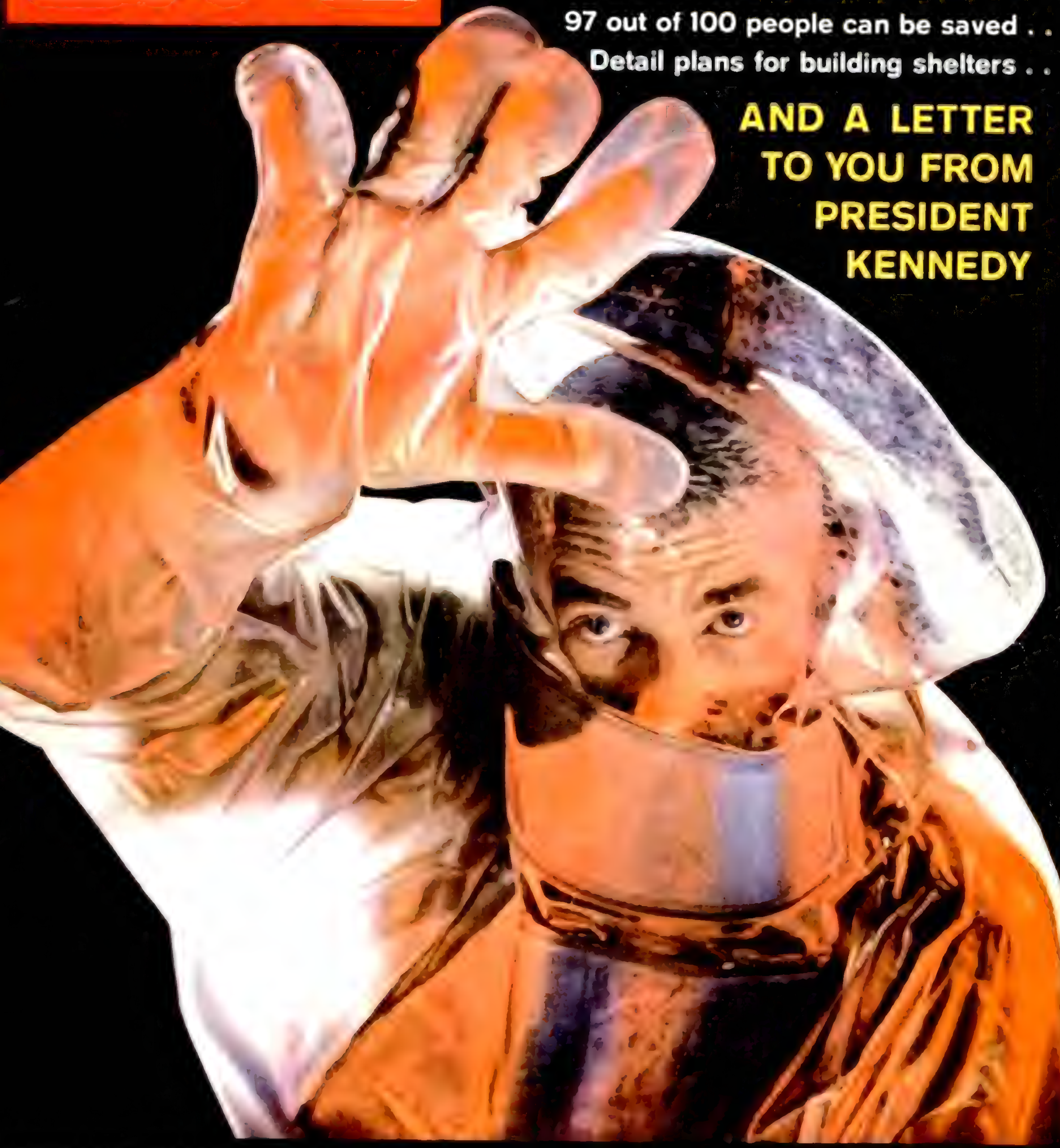
HOW YOU CAN

SURVIVE FALLOUT

97 out of 100 people can be saved . . .

Detail plans for building shelters . . .

AND A LETTER TO YOU FROM PRESIDENT KENNEDY



CIVILIAN FALLOUT SUIT

SEPTEMBER 15 · 1961 · 20¢

A MESSAGE TO YOU FROM THE PRESIDENT

The White House
September 7, 1961

My Fellow Americans:

Nuclear weapons and the possibility of nuclear war are facts of life we cannot ignore today. I do not believe that war can solve any of the problems facing the world today. But the decision is not ours alone.

The government is moving to improve the protection afforded you in your communities through civil defense. We have begun, and will be continuing throughout the next year and a half, a survey of all public buildings with fallout shelter potential, and the marking of those with adequate shelter for 50 persons or more. We are providing fallout shelter in new and in some existing federal buildings. We are stocking these shelters with one week's food and medical supplies and two weeks' water supply for the shelter occupants. In addition, I have recommended to the Congress the establishment of food reserves in centers around the country where they might be needed following an attack. Finally, we are developing improved warning systems which will make it possible to sound attack warning on buzzers right in your homes and places of business.

More comprehensive measures than these lie ahead, but they cannot be brought to completion in the immediate future. In the meantime there is much that you can do to protect yourself—and in doing so strengthen your nation.

I urge you to read and consider seriously the contents of this issue of LIFE. The security of our country and the peace of the world are the objectives of our policy. But in these dangerous days when both these objectives are threatened we must prepare for all eventualities. The ability to survive coupled with the will to do so therefore are essential to our country.

John F. Kennedy

Fallout Shelters

YOU COULD BE AMONG THE 97% TO SURVIVE IF YOU FOLLOW ADVICE ON THESE PAGES . . . HOW TO BUILD SHELTERS . . . WHERE TO HIDE IN CITIES . . . WHAT TO DO DURING AN ATTACK

Proceedings of the Symposium
held at Washington, D. C.
April 19-23, 1965 by the
Subcommittee on Protective Structures,
Advisory Committee on Civil Defense,
National Academy of Sciences—
National Research Council

Protective Structures

for

CIVILIAN POPULATIONS

1966

THE PROTECTION AGAINST FALLOUT RADIATION AFFORDED BY CORE SHELTERS IN A TYPICAL BRITISH HOUSE

Daniel T. Jones
Scientific Adviser, Home Office, London

Protective Factors in a Sample of British Houses (Windows Blocked)

Protective Factor	Percentage of Houses
< 25	36%
25-39	28%
40-100	29%
> 100	7%

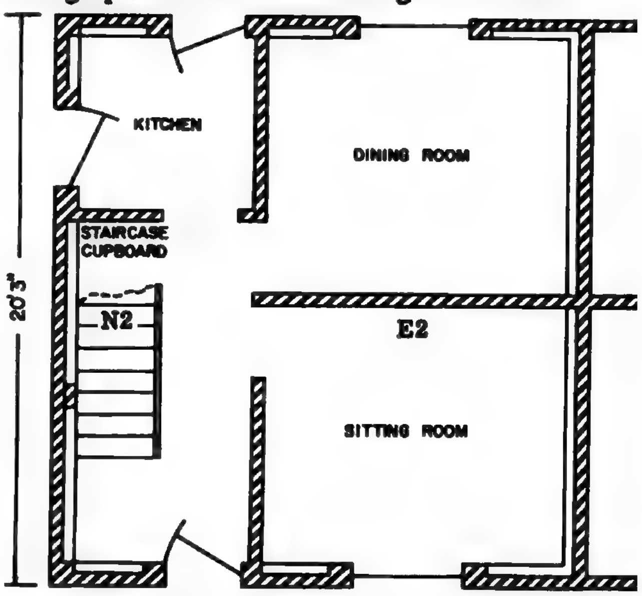
"A very much improved protection could be obtained by constructing a shelter core. This means a small, thick-walled shelter built preferably inside the fallout room itself, in which to spend the first critical hours when the radiation from fallout would be most dangerous."(1)

The full-scale experiments were carried out at the Civil Defense School at Falfield Park.(2)

In the staircase construction, the shelter consisted of the cupboard under the stairs, sandbags being placed on treads above and at the sides.

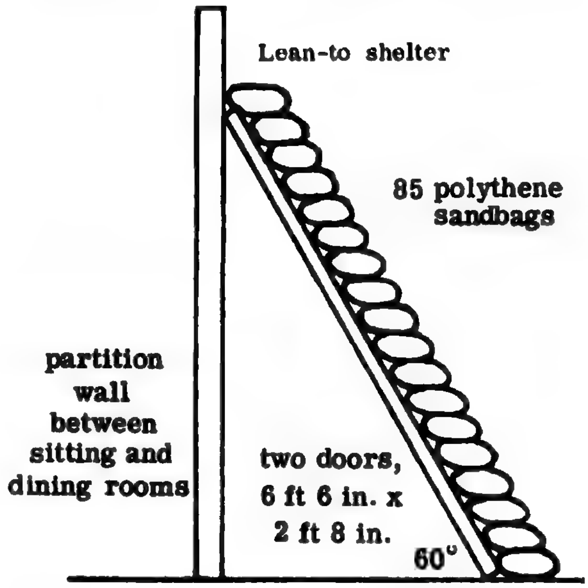
A 93 curies cobalt-60 source was used.

1. Six sandbags per tread, and a double layer on the small top landing. 96 sandbags were used.
2. As (1), together with a 4-ft-high wall of sandbags along the external north wall. 160 sandbags were used.
3. As (2), together with 4-ft-high walls of sandbags along the kitchen/cupboard partition wall and along the passage partition. 220 sandbags were used.



sandbags 24 in. x 12 in. when empty; 16 in. x 9 in. x 4 in. when filled with 25 lb of sand.

9 in. brick walls The windows and doors were not blocked	Position	contribution r/hr/c/ft^2 Ground	Roof	Protective Factor
House only	E2	15.0	8.4	21
Lean-to	E2	10.4	2.4	39
Staircase cupboard:				
Stairs only sandbagged	N2	29.2	5.3	14
Stairs and outer wall sandbagged	N2	16.4	4.6	24
Stairs, outer wall, kitchen wall and corridor partition sandbagged	N2	8.8	1.8	47



floor area 21 sq ft.

1. Civil Defence Handbook No. 10, HMSO, 1963.
2. Perryman, A. D., Home Office Report CD/SA 117.

BLAST AND OTHER THREATS

Harold Brode
The RAND Corporation, Santa Monica, California

Chemical High-Explosive Weapons

As in past aerial warfare, bombs and missiles carrying chemical explosives to targets are capable of extensive damage only when delivered in large numbers and with high accuracy.

Biological Warfare

Most biological agents are inexpensive to produce; their effective dissemination over hostile territories remains the chief deterrent to their effective employment. Twenty square miles is about the area that can be effectively covered by a single aircraft; large area coverage presents a task for vast fleets of fairly vulnerable planes flying tight patterns at modest or low altitudes. While agents vary in virulence and in their biologic decay rate, most are quite perishable in normal open-air environments. Since shelter and simple prophylactic measures can be quite effective against biological agents, there is less likelihood of the use of biological warfare on a wholesale basis against a nation, and more chance of limited employment on population concentrations —perhaps by covert delivery, since shelters with adequate filtering could insure rather complete protection to those inside.

Chemical Weapons

Chemical weapons, like biological weapons, are relatively inexpensive to create, but face nearly insurmountable logistics problems on delivery. Although chemical agents produce casualties more rapidly, the greater amounts of material to deliver seriously limit the likelihood of their large-scale deployment. Furthermore, chemical research does not hold promise of the development of significantly more toxic chemicals for future use.

Radiological Weapons

The advantages of such modifications are much less real than apparent. In all weapons delivered by missiles, minimizing the payload and total weight is very important. If the total payload is not to be increased, then the inclusion of inert material to be activated by neutrons must lead to reductions in the explosive yield. If all the weight is devoted to nuclear explosives, then more fission-fragment activity can be created, and it is the net difference in activity that must be balanced against the loss of explosive yield. As it turns out, a fission explosion is a most efficient generator of activity, and greater total doses are not achieved by injecting special inert materials to be activated.

Perret, W.R., Ground Motion Studies at High Incident Overpressure, The Sandia Corporation, Operation PLUMBBOB, WT-1405, for Defense Atomic Support Agency Field Command, June 1960.

The Neutron Bomb

The neutron bomb, so called because of the deliberate effort to maximize the effectiveness of the neutrons, would necessarily be limited to rather small yields—yields at which the neutron absorption in air does not reduce the doses to a point at which blast and thermal effects are dominant. The use of small yields against large-area targets again runs into the delivery problems faced by chemical agents and explosives, and larger yields in fewer packages pose a less stringent problem for delivery systems in most applications. In the unlikely event that an enemy desired to minimize blast and thermal damage and to create little local fallout but still kill the populace, it would be necessary to use large numbers of carefully placed neutron-producing weapons burst high enough to avoid blast damage on the ground, but low enough to get the neutrons down. In this case, however, adequate radiation shielding for the people would leave the city unscathed and demonstrate the attack to be futile.

The thermal radiation from a surface burst is expected to be less than half of that from an air burst, both because the radiating fireball surface is truncated and because the hot interior is partially quenched by the megatons of injected crater material.

SUPERSEISMIC GROUND-SHOCK MAXIMA (AT 5-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 340\,\Delta P_s/C_L$ ± 30 per cent. Here acceleration is measured in g's and overpressure (ΔP_s) in pounds per square inch. An empirical refinement requires C_L to be defined as the seismic velocity (in feet per second) for rock, but as three fourths of the seismic velocity for soil.

OUTRUNNING GROUND-SHOCK MAXIMA (AT ~10-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 2 \times 10^5/C_L r^2$ + factor 4 or -factor 2. Acceleration is measured in g's, and r is the scaled radial distance—i.e., $r = R/W^{1/3}$ kft/(mt)$^{1/3}$.

Data taken on a low air-burst shot in Nevada indicate an exponential decay of maximum displacement with depth. For the particular case of a burst of ~ 40 kt at 700 ft, some measurements were made as deep as 200 ft below the surface of Frenchman Flat, a dry lake bed, which led to the following approximate decay law, according to Perret.

$$\delta = \delta_0 \exp(-0.017D),$$

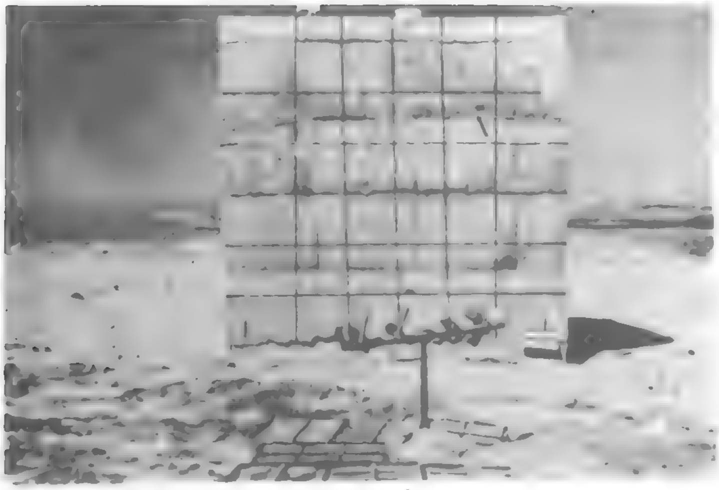
where δ represents the maximum vertical displacement induced at depth D, δ_0 is the maximum displacement at the surface, and D is the depth in feet.

MODEL ANALYSIS

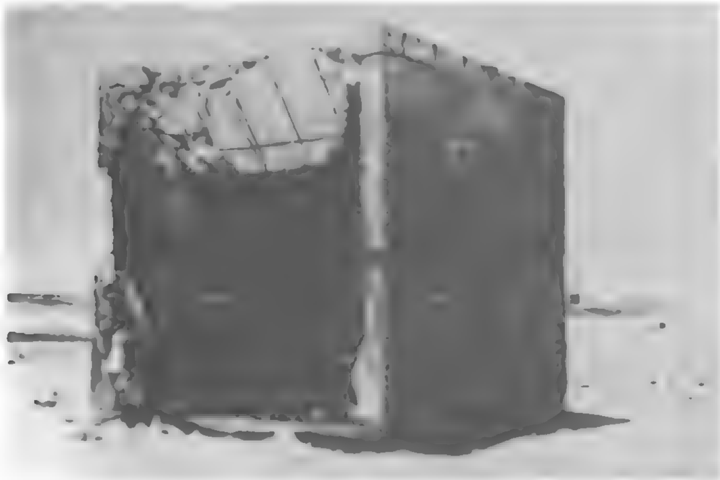
Mr. Ivor Ll. DAVIES
Suffield Experimental Station
Canadian Defense Research Board
Ralston, Alberta, Canada

Nuclear-Weapon Tests

In 1952 we fired our first nuclear device, effectively a "nominal" weapon, at Monte Bello, off northwest Australia. To the blast loading from this weapon we exposed a number of reinforced-concrete cubicle structures that had been designed for the dynamic loading conditions, and for which we made the best analysis of response we were competent to make at that time. Our estimates of effects were really a dismal failure. The structures were placed at pressure levels of 30, 10, and 6 psi, where we expected them to be destroyed, heavily damaged with some petaling of the front face, and extensively cracked, respectively. In fact, the front face of the cubicle at 30 psi was broken inwards; failure had occurred along both diagonals, and the four triangular petals had been pushed in. At the 10-psi level, where we had three cubicles, each with a different wall thickness (6, 9, and 12 in.), we observed only light cracking in the front face of that cubicle with the least thick wall (6 in.). The other two structures were apparently undamaged, as was the single structure at the 6-psi level.



10 p.s.i.



34 p.s.i.

Dynamic tests, Monte Bello cubicles.

In 1957, the first proposals were made for the construction of the underground car park in Hyde Park in London. The Home Office was interested in this project since, in an emergency, the structure could be used as a shelter. Consequently a request was made to us at Atomic Weapons Research Establishment (A.W.R.E.) to design a structure that would be resistant to a blast loading of about 50 psi, and to test our design on the model scale.

Using the various load-deformation curves obtained in this test, an estimate was made of the response of the structure to blast loading. Of particular interest was the possible effect of 100 tons of TNT, the first 100-ton trial at Suffield in Alberta.

A total of seven more models was made; six were shipped to Canada and placed with the top surface of the roof flush with the ground and at positions where peak pressures of 100, 80, 70, 60, 50, and 40 psi were expected. The seventh model was kept in England for static testing at about the time of firing. The results were not as expected. In the field, the four models farthest from the charge were apparantly undamaged; we could see no cracking with the eye, nor did soaking the models with water reveal more than a few hair cracks. The model nearest the charge was lightly cracked in the roof panels and beams, and one of the columns showed slight spalling at the head. This model had been exposed to a peak pressure of 110 psi.

Davies, I. Ll., Effects of Blast on Reinforced Concrete Slabs, and the Relationship with Static Loading Characteristics (U). United Kingdom, Operation BUFFALO - Target Response Tests, AWRE Report T 46/57 (CONFIDENTIAL report), August 1957.

Wood, A. J., The Effect of Earth Covers on the Resistance of Trench Shelter Roofs (U). United Kingdom, Operation BUFFALO-Target Response Target Response Tests, AWRE Report T 47/57 (CONFIDENTIAL report), August 1957.

O'Brien, T. P., Rowe, R. D., and Hance, R. J., The Effect of Atomic Blast on Wall Panels (U). United Kingdom, FWE-36 (CONFIDENTIAL report), April 1955.

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HOME OFFICE
SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

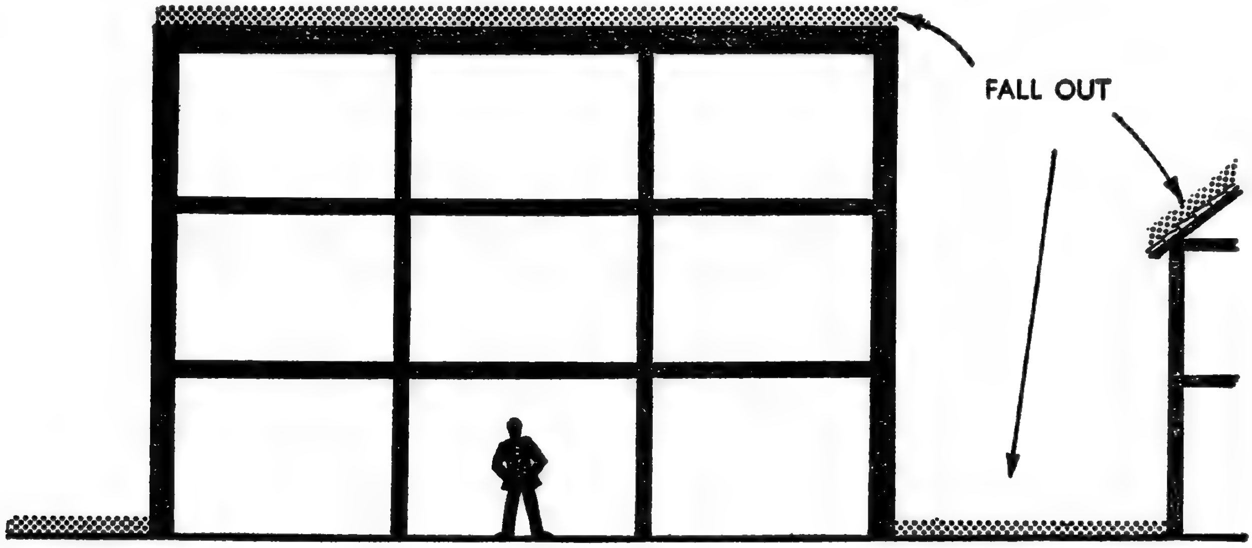
LONDON
HER MAJESTY'S STATIONERY OFFICE
1956

Practical protection

88 Large buildings with a number of storeys, especially if they are of heavy construction, provide much better protection than small single-storey structures (see Figure 4). Houses in terraces likewise provide much better protection than isolated houses because of the shielding effect of neighbouring houses.

GOOD PROTECTION

Solidly constructed multi-storeyed building with occupants well removed from fall-out on ground and roof. The thickness of floors and roof overhead, and the shielding effect of other buildings, all help to cut down radiation



BAD PROTECTION

Isolated wooden bungalow

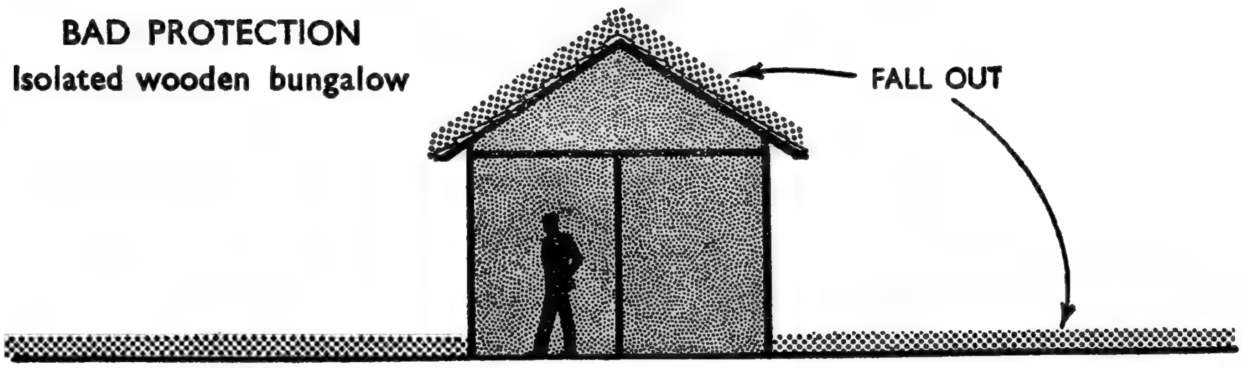


FIGURE 4

Examples of good and bad protection afforded by buildings against fall-out.

89 It is estimated that the protection factor (the factor by which the outside dose has to be divided to get the inside dose) of a ground floor room in a two-storey house ranges from 10 to about 50, depending on wall thickness and the shielding afforded by neighbouring buildings. The corresponding figures for bungalows are about 10–20, and for three-storey houses about 15–100. An average two-storey brick house in a built-up area gives a factor of 40, but basements, where the radiation from outside the house is attenuated by a very great thickness of earth, have protection factors ranging up to 200–300. A slit trench with even a light cover of boards or corrugated iron without earth overhead gives a factor of 7, and if 1 ft. of earth cover is added the

factor rises to 100. If the trench can be covered with 2 or 3 feet of earth then a factor of more than 200–300 can be obtained (see Figure 5).

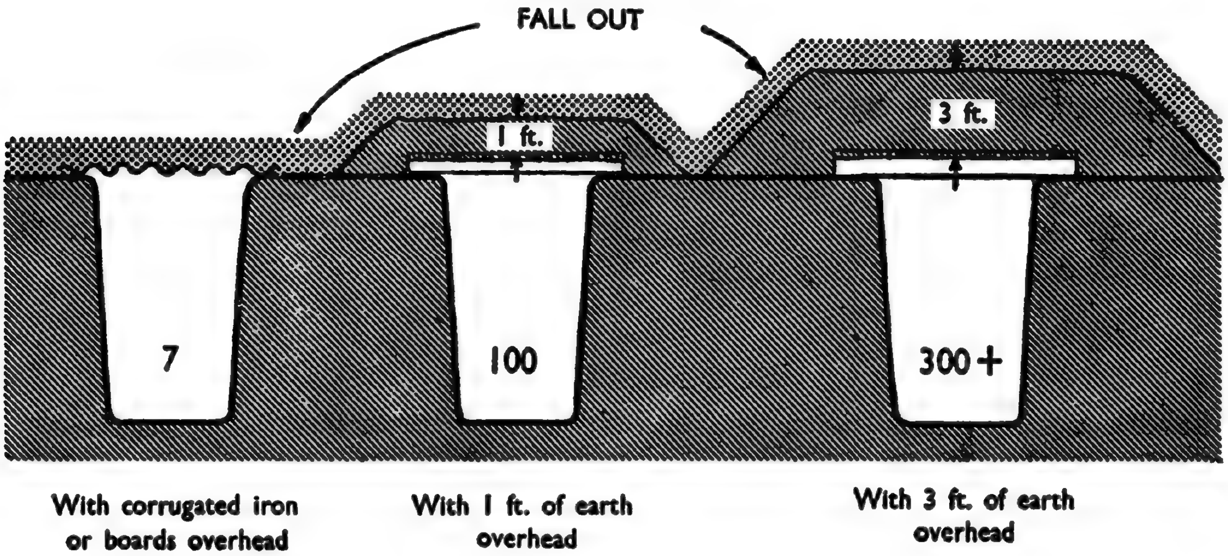


FIGURE 5
Protection factors in slit trenches (the factor by which the outside dose is divided to get the inside dose).

Choosing a refuge room

90 In choosing a refuge room in a house one would select a room with a minimum of outside walls and make every effort to improve the protection of such outside walls as there were. In particular the windows would have to be blocked up, e.g. with sandbags. Where possible, boxes of earth could be placed round an outside wall to provide additional protection, and heavy furniture (pianos, bookcases etc.) along the inside of the wall would also help. A cellar would be ideal. Where the ground floor of the house consists of boards and timber joists carried on sleeper walls it may be possible to combine the high protection of the slit trench with some of the comforts of the refuge room by constructing a trench under the floor.

Once a trap door had been cut in the floor boards and joists and the trench had been dug, there would be no further interference with the peace-time use of the room.

Estimated under-cover doses in the fall-out area

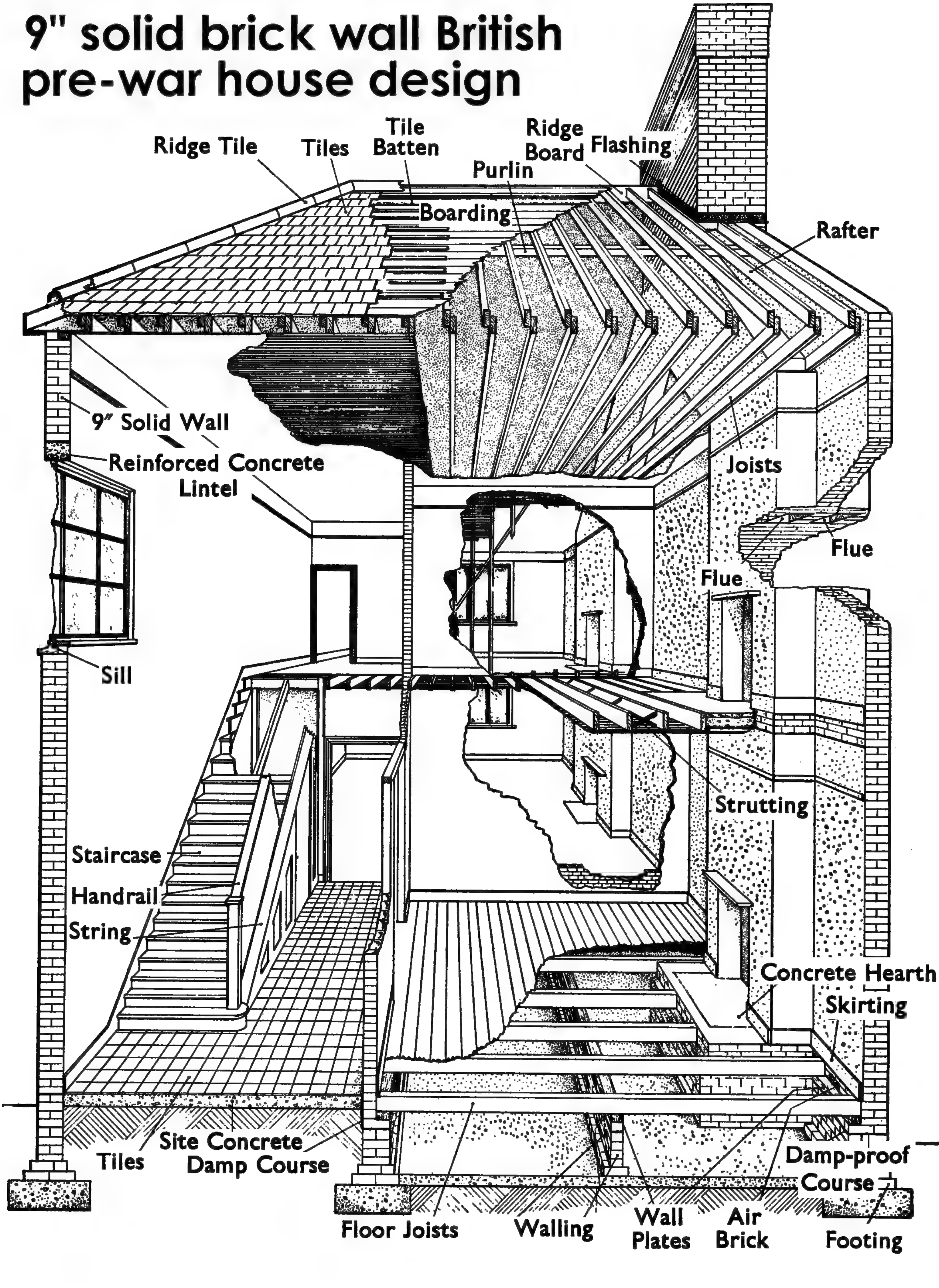
91 Taking an average protective factor of 40 for a two-storey house in a built-up area, the doses accumulated in 36 hours for the ranges referred to in the U.S. Atomic Energy Commission Report (paragraph 84) would have been:—

190	miles downwind		7½r
160	,,	,,	12½r
140	,,	,,	20r

15 Megatons
Bravo 1954

which are all well below the lowest figure of 25r referred to in Table 1. At closer ranges along the axis of the fall-out, the doses accumulated in 36 hours would have been much higher, but over most of the contaminated area—with this standard of protection—the majority of those affected would have been saved from death, and even from sickness, by taking cover continuously for the first 36 hours.

9" solid brick wall British pre-war house design



5. Radiation sickness

Assume dose incurred in a single shift (3–4 hours) by the "average" man, over the whole body:—

25 roentgens		—No obvious harm.
100	„	—Some nausea and vomiting.
500	„	—Lethal to about 50 per cent. people (death up to 6 weeks later).
800	„	or more—Lethal to all (death up to 6 weeks later).

Note: If dose spread uniformly over 2–3 days, then 60 roentgens could be incurred with no more effect than 25 roentgens in a single exposure of 3–4 hours.

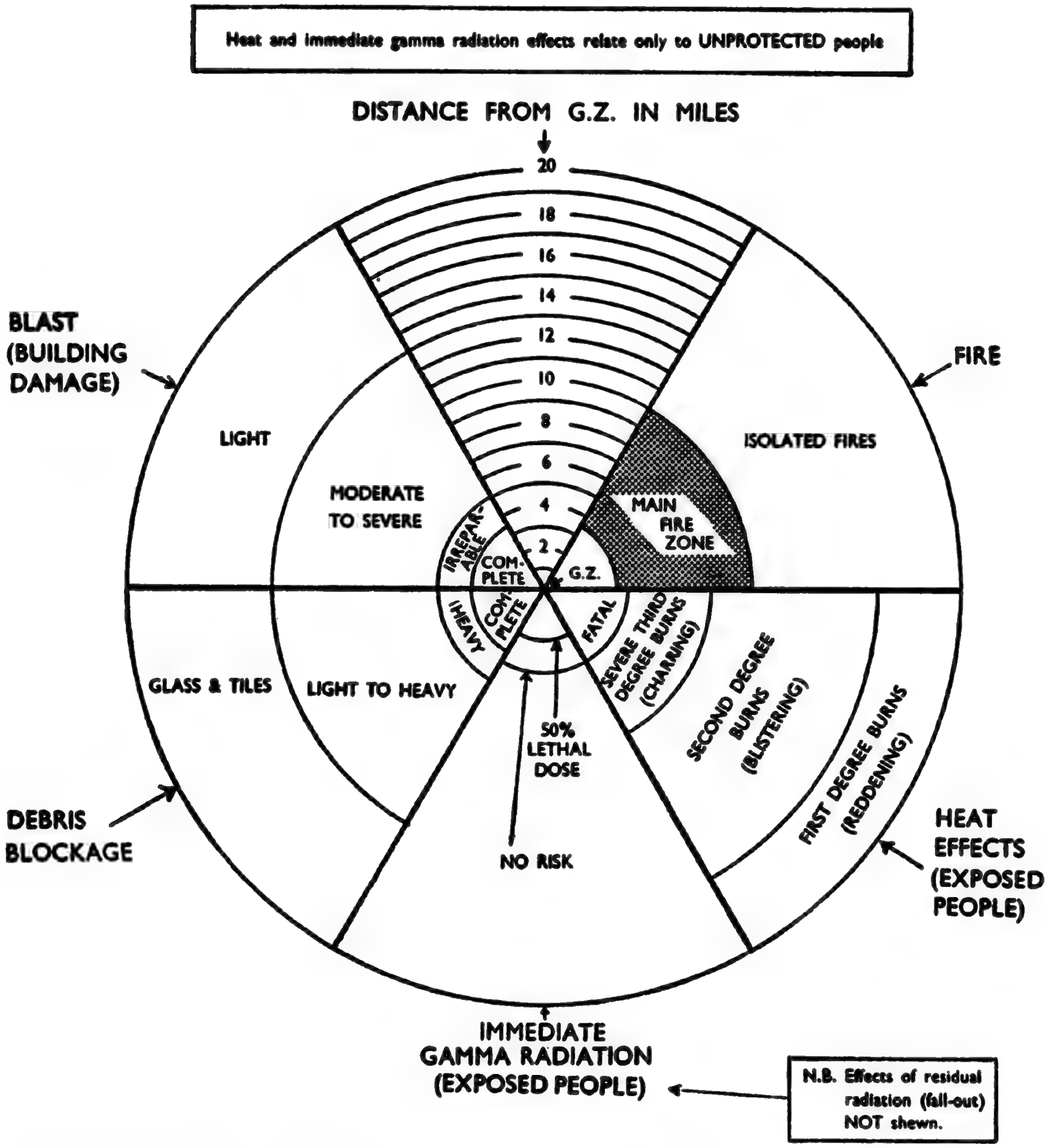


FIGURE 11

Combined effects (excluding residual radioactivity) from a 10 megaton ground burst bomb. Heat and immediate gamma radiation effects relate only to UNPROTECTED people.

HOME OFFICE
SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE
Volume I

PAMPHLET No. 2

RADIOACTIVE FALL-OUT

PROVISIONAL SCHEME OF PUBLIC CONTROL

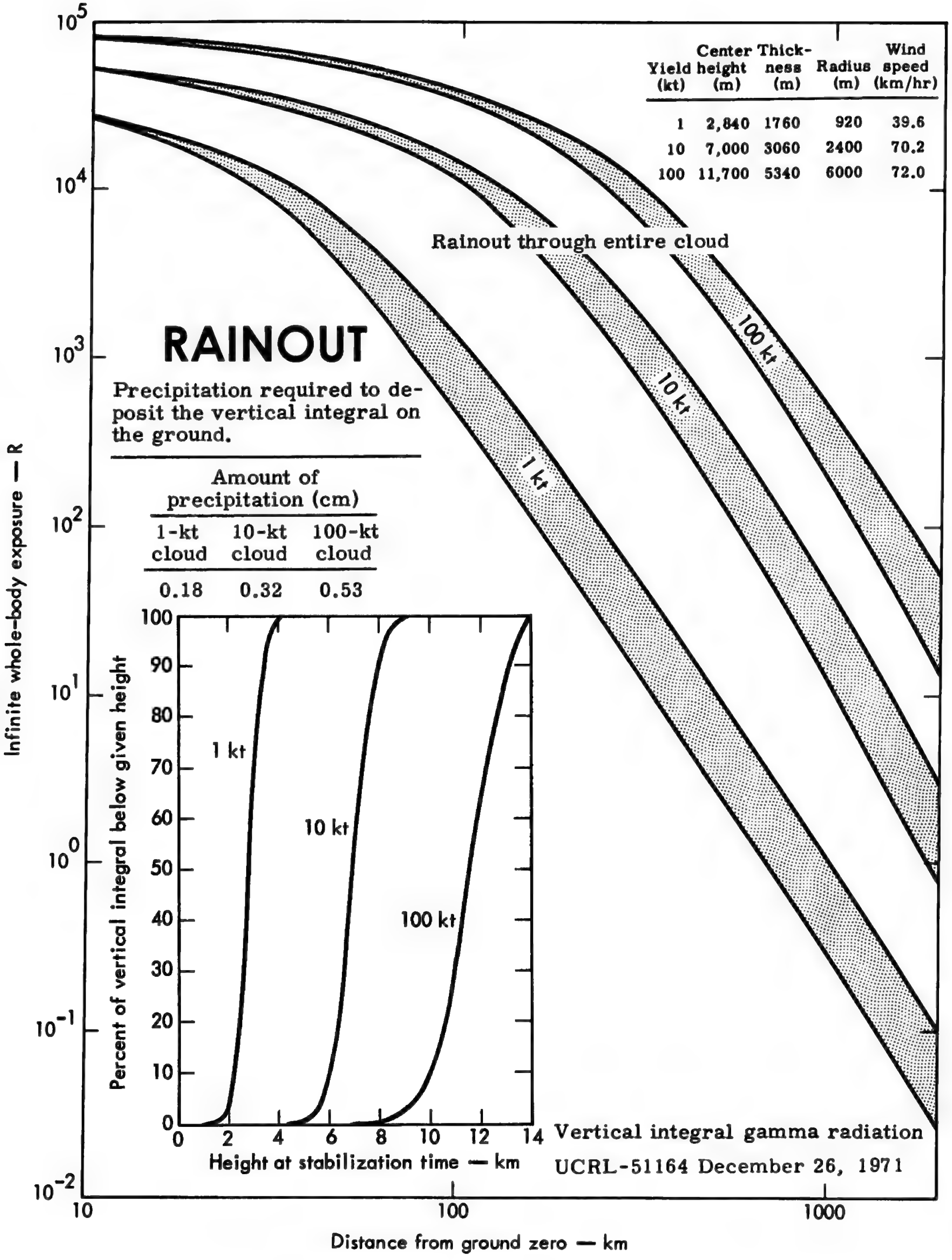
LONDON
HER MAJESTY'S STATIONERY OFFICE
1956

Radioactive Fall-out—Summary of Provisional Control Zones

Zone	Definition of Zone Boundaries	Range of Cumulative Doses in open at 48 hours	Summary of permissible and recommended action	Range of Cumulative Doses assuming observance of control rules
W	Outer: Limit of area placed under "Black Warning" (*see* Footnote). Inner: 0·3 r.p.h. at 48 hrs.	Up to 80r	Complete release from refuge as soon as dose-rate fell to 0·3 r.p.h. or, if the rate had not reached that figure, when fall-out was complete.	At 48 hrs. Below 2r
X	Outer: 0·3 r.p.h. at 48 hrs. Inner: 3 r.p.h. at 48 hrs.	80–800r	Qualified release from refuge after 48 hrs.—indoor workers to follow normal occupations, but not to exceed 4 hrs. per day in the open. Outdoor workers to work half shifts for next five days. At the end of this period the zone would be normal, except that all would be advised to be out of doors as little as possible and not in any case to exceed 8 hrs. per day in the open for the next three months.	At 48 hrs. 2-20r At 7 days 6-60r At 5 wks. 12-120r At 3 mths. 14-145r
Y	Outer: 3 r.p.h. at 48 hrs. Inner: 10 r.p.h. at 48 hrs.	800-2,800r	Release from refuge under stringent control after 48 hrs. For the next 12 days people should not leave their refuge for longer than necessary. Time in the open should not exceed 2 hrs. per day and time under cover, but not in refuge, a further 8 hrs. On this basis essential indoor workers should be able to get to their places of work, but outdoor work would remain suspended; a relaxation would be possible after the first fortnight and further easement in another three weeks. For the rest of the first year, however, people in this zone should not exceed 8 hrs. a day in the open.	At 48 hrs. 20-70r At 14 days 50-170r At 5 wks. 70-240r At 3 mths. 95-330r
Z	10 r.p.h. at 48 hrs.	Above 2,800r	All movement outside refuge accommodation in this zone would be dangerous. People should remain in refuge until instructions for clearance were given—they should then leave the zone by the quickest available route if they had means of transport or wait in their refuge to be collected if they had not. The clearance operation might start after 48 hrs. and removal from the zone would be for at least 3 months.	At 48 hrs.—Above 70r

The initial Zone W boundary would be defined by the boundaries of a series of warning districts on the flanks of the fall-out. After 48 hrs. Zone W would for public control purposes have disappeared: its outer boundary would have moved during the period to coincide with the outer boundary of Zone X.

The question of defining an area extending in some places beyond Zone W in which there might be an agricultural hazard is being studied.


RAINOUT
Precipitation required to deposit the vertical integral on the ground.
Amount of precipitation (cm)
1-kt cloud 10-kt cloud 100-kt cloud
0.18 0.32 0.53
Yield (kt) Center height (m) Thickness (m) Radius (m) Wind speed (km/hr)
1 2,840 1760 920 39.6
10 7,000 3060 2400 70.2
100 11,700 5340 6000 72.0
Rainout through entire cloud
100 kt
10 kt
1 kt
Infinite whole-body exposure — R
Distance from ground zero — km
Percent of vertical integral below given height
Height at stabilization time — km
Vertical integral gamma radiation
UCRL-51164 December 26, 1971

FOR RELEASE AT 4:00 P.M. (E.S.T.)
TUESDAY, FEBRUARY 15, 1955

A REPORT

BY THE UNITED STATES ATOMIC ENERGY COMMISSION

ON THE EFFECTS OF HIGH-YIELD NUCLEAR EXPLOSIONS

FALLOUT PATTERN OF 1954 TEST IN THE PACIFIC

19. Data from this test permits estimates of casualties which would have been suffered within this contaminated area if it had been populated. These estimates assume: (1) that the people in the area would ignore even the most elementary precautions; (2) that they would not take shelter but would remain out of doors completely exposed for about 36 hours; and (3) that in consequence they would receive the maximum exposure. Therefore, it will be recognized that the estimates which follow are what might be termed extreme estimates since they assume the worst possible conditions.

PROTECTION AGAINST FALLOUT

26. In an area of heavy fallout the greatest radiological hazard is that of exposure to external radiation. Simple precautionary measures can greatly reduce the hazard to life. Exposure can be reduced by taking shelter and by utilizing simple decontamination measures until such times as persons can leave the area. Test data indicate that the radiation level, i.e., the rate of exposure, indoors on the first floor of an ordinary frame house in a fallout area would be about one-half the level out of doors. Even greater protection would be afforded by a brick or stone house. Taking shelter in the basement of an average residence would reduce the radiation level to about one-tenth that experienced out of doors.

29. If fallout particles come into contact with the skin, hair or clothing, prompt decontamination precautions such as have been outlined by the Federal Civil Defense Administration will greatly reduce the danger. These include such simple measures as thorough bathing of exposed parts of the body and a change of clothing.

30. If persons in a heavy fallout area heeded warning or notification of an attack and evacuated the area or availed themselves of adequate protective measures, the percentage of fatalities would be greatly reduced even in the zone of heaviest fallout.

Foreword

If the country were ever faced with an immediate threat of nuclear war, a copy of this booklet would be distributed to every household as part of a public information campaign which would include announcements on television and radio and in the press. The booklet has been designed for free and general distribution in that event. It is being placed on sale now for those who wish to know what they would be advised to do at such a time.

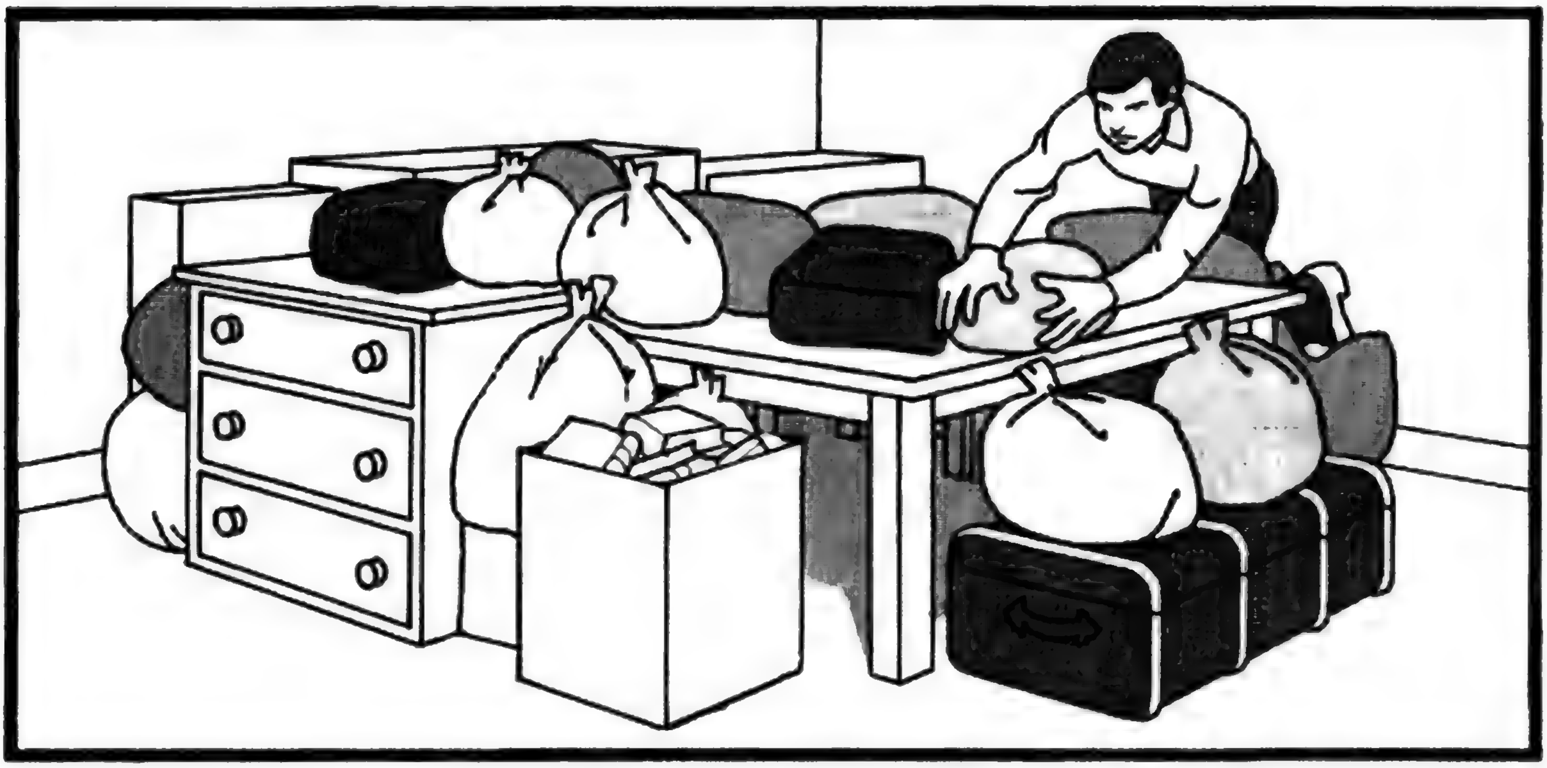
May 1980

Protect and Survive
ISBN 0 11 3407289

If Britain is attacked by nuclear bombs or by missiles, we do not know what targets will be chosen or how severe the assault will be.

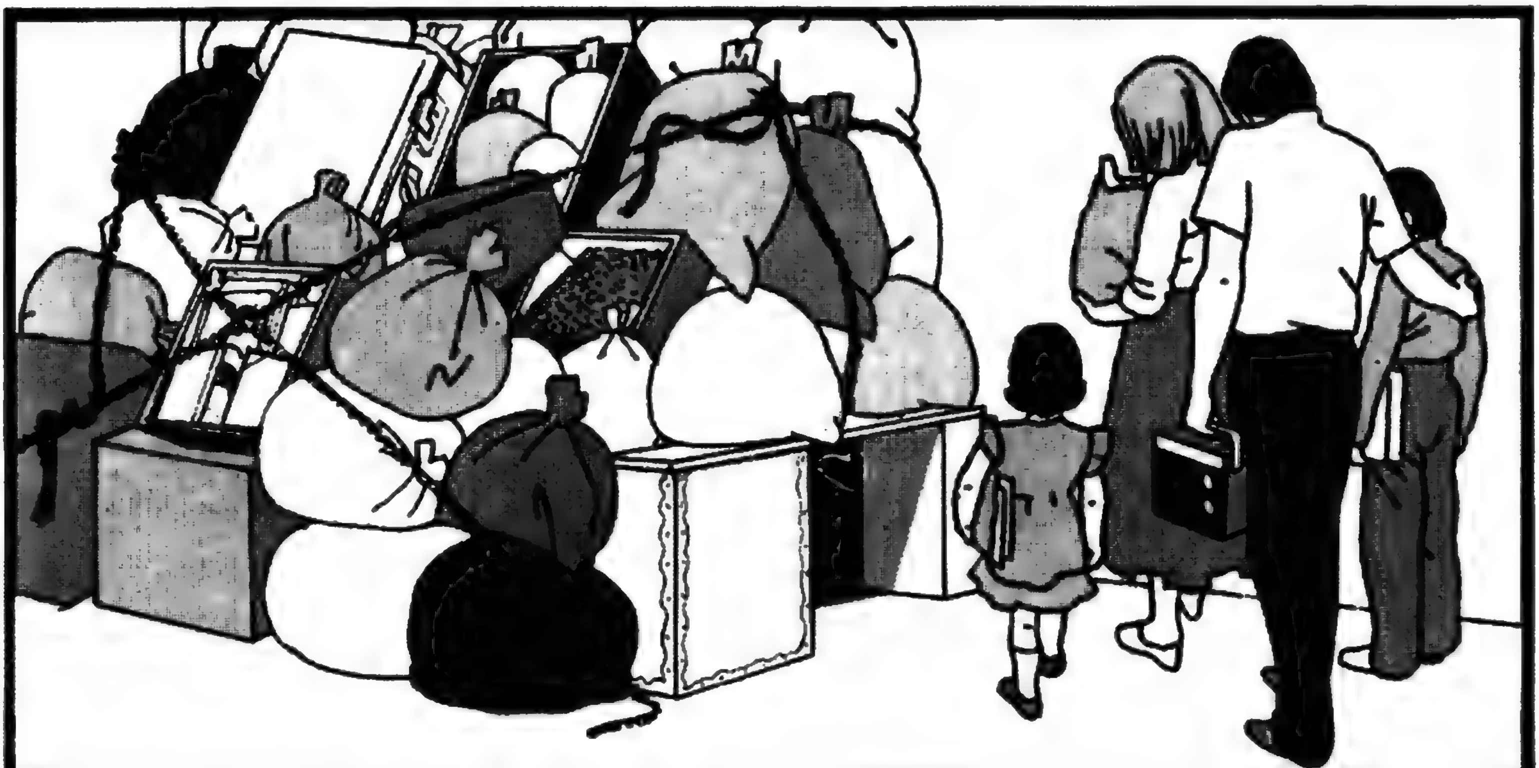
If nuclear weapons are used on a large scale, those of us living in the country areas might be exposed to as great a risk as those in the towns. The radioactive dust, falling where the wind blows it, will bring the most widespread dangers of all. No part of the United Kingdom can be considered safe from both the direct effects of the weapons and the resultant fall-out.

The dangers which you and your family will face in this situation can be reduced if you do as this booklet describes.



If there is structural damage from the attack you may have some time before a fall-out warning to do minor jobs to keep out the weather – using curtains or sheets to cover broken windows or holes.

If you are out of doors, take the nearest and best available cover as quickly as possible, wiping all the dust you can from your skin and clothing at the entrance to the building in which you shelter.



FIRST CASUALTIES OF THE H-BOMB

by DWIGHT MARTIN

Five weeks out of Yaizu, her home port 120 miles southeast of Tokyo, the 99-ton tuna trawler *Fukuryu Maru* ("Fortunate Dragon") hove to at a position 166°30′ east longitude and 11°52′ north latitude. She dropped anchor and cast her nets at 5:30 a.m. on March 1. The *Fortunate Dragon*'s position, though her skipper and crew did not realize it, was 71 miles east-northeast of Bikini atoll and 14 miles outside the boundary of the restricted zone of the U.S. government's atomic testing area.

A calm sea was running and the weather was clear. Sunrise was at 6:09 a.m. and visibility was excellent. The *Fortunate Dragon*'s skipper, 24-year-old Tadaichi Tsutsui, was standing watch on the bridge, and eight crewmen were enthusiastically hauling in their first nets. After nearly three weeks of poor catches near Midway Island, the *Fortunate Dragon* had finally run into luck in more southern waters and her hold was already filled with 16,500 pounds of fat tuna. It was just a few seconds before 6:12 a.m.

"Then," said Crewman Sanjiro Masuda later, "we saw flashes of fire, as bright as the sun itself, rising to the sky. They rose about 10 degrees from the horizon and the sky around them glowed fiery red and yellow.

But Captain Tsutsui was getting more and more uneasy: "I thought, 'The bomb tests were being conducted over coral reefs. It could be pulverized coral ash, couldn't it?' " He thought some more about *shi no hai*, then ordered the crew to up anchor. The trawler steamed for home, 2,000 miles away.

"On the first night," said Radioman Aikichi Kuboyama, "we were unable to eat our supper. We tried drinking some sake (rice wine) to improve our appetites, but our appetites would not improve and the sake did not make us drunk. We were very depressed. Some of the crew grumbled '*pikadon*' but others said it couldn't be. I think someone said it was probably dust from some volcanic explosion."

AT HER DOCK the unfortunate *Fortunate Dragon*, still radioactive, floats untended by crewmen.

"We made port in Yaizu at 6 a.m. on March 14. We were now quite sick and frightened, and we went to see Dr. Toshisuke Oii at Kyoritsu hospital. He said we had severe burns and gave us some white ointment."

LIFE
Vol. 36, No. 13 March 29, 1954

SOME EFFECTS OF

Ionizing Radiation

ON HUMAN BEINGS

A Report on the Marshallese and Americans Accidentally Exposed to Radiation from Fallout and a Discussion of Radiation Injury in the Human Being

from the
Naval Medical Research Institute
Bethesda 14, Maryland
U. S. Naval Radiological Defense Laboratory
San Francisco, California
and
Medical Department
Brookhaven National Laboratory
Upton, New York

Edited by
E. P. Cronkite
V. P. Bond
and C. L. Dunham

UNITED STATES
ATOMIC ENERGY COMMISSION
JULY 1956

Report TID-5358

Extensive lesions in 13 year old boy at 45 days post-exposure. Case 26.

PLATE 5.—*Hyperpigmented raised plaques and bullae on dorsum of feet and toes at 28 days. One lesion on left foot shows deeper involvement. Feet were painful at this time.*

PLATE 8.—*Same case as in Plate 5, six months later. Foot lesions have healed with repigmentation, except depigmented spots persist in small areas where deeper lesions were.*

PLATE 17.—*Epilation in 7 yr. old girl at 28 days. Case 72.*

PLATE 18.—*Same case as in Plate 17, six months after exposure showing complete regrowth of normal hair.*

Figure 1.1—*Typical construction of the Marshallese homes to illustrate the exposure environment of the Marshallese and the lack of shielding from gamma radiation.*

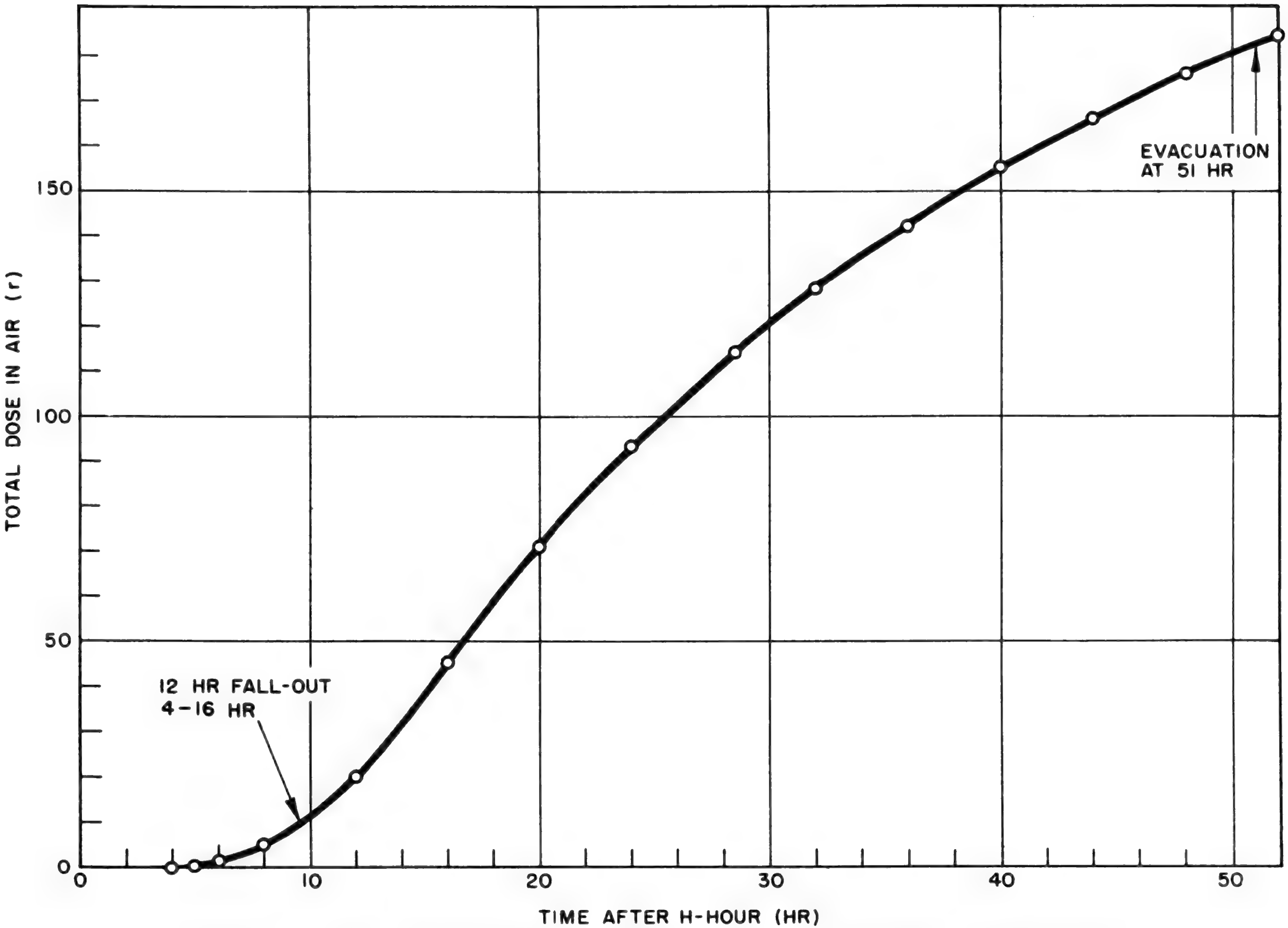


Figure 1.3—*The accumulation of gamma dose as a function of time after commencement of fallout on Rongelap*

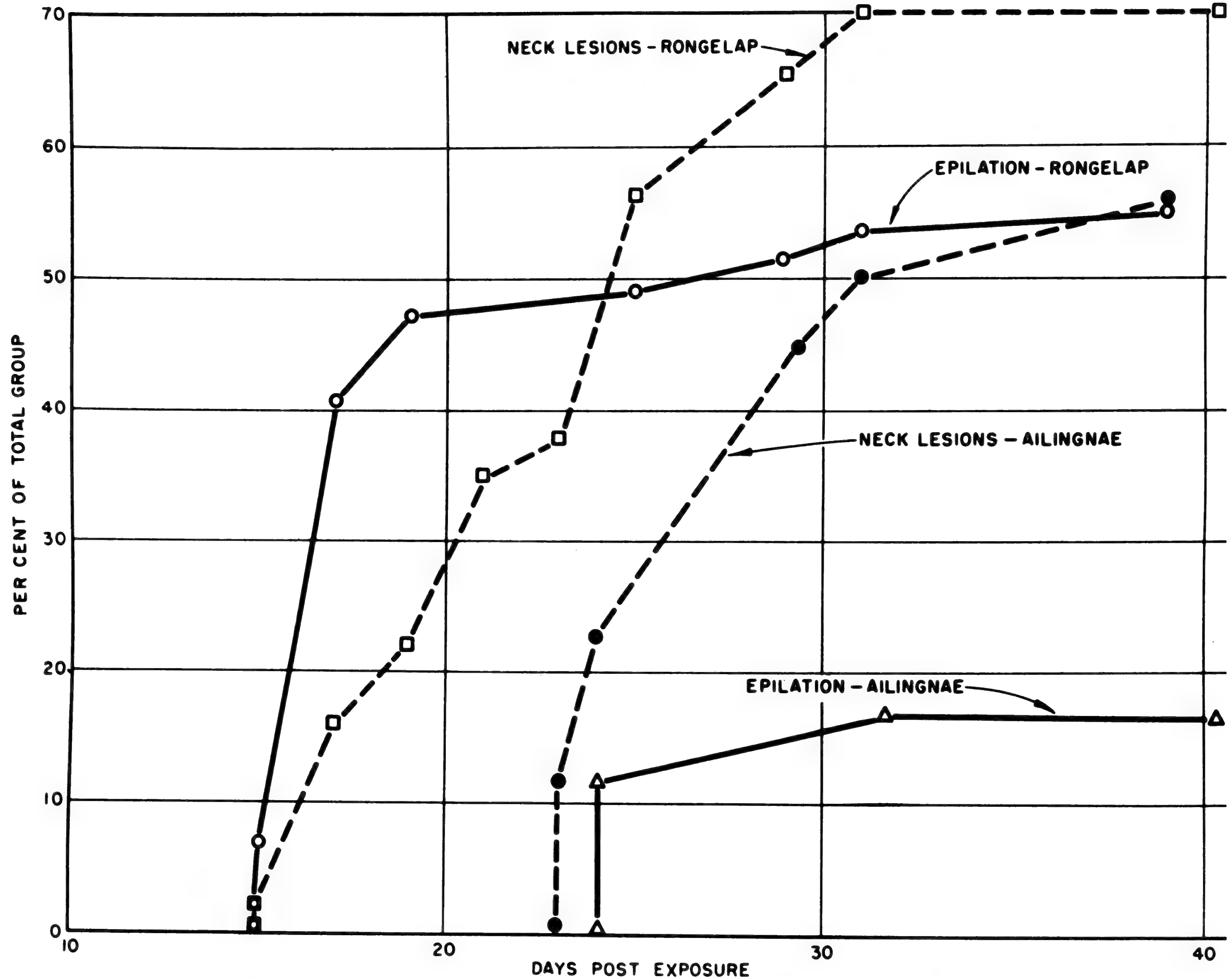


FIGURE 3.1.—*Comparison of the Incidence and Time of Appearance of Epilation and Neck Lesions in the Rongelap and Ailinginae Groups.*

On Rongerik (Group III) a set of film badge readings were obtained which constitute the only direct evidence of total dose. Several badges worn both outdoors and inside lightly constructed buildings on the island read about 50 to 65 r, and one badge which remained outdoors over the 28.5 hour period read 98 r. Another group of badges, kept indoors inside a steel refrigerator, read 38 r.

A long fallout probably would not be uniformly heavy throughout, the first portion being the most intense and the balance decreasing with time. The total phenomenon would thus tend toward the effect of a shorter fallout. This is supported by monitor data from other nuclear events, where initially heavy fallout is reported to produce a peak of air-borne radioactivity soon after arrival, with the airborne activity level then decreasing.

Itching and burning of the skin occurred in 28 percent of Group I (Rongelap), 20 percent of Group II (Ailinginae), 5 percent of Group III (Americans), and none of Group IV (Utirik). Three people in Group I and one in Group II complained of itching and burning of the eyes and lacrimation.

About two-thirds of Group I were nauseated during the first 2 days and one-tenth vomited and had diarrhea. One individual in Group II was nauseated. In Groups III and IV there were no gastrointestinal (GI) symptoms.

Between The 33rd and 43rd post-exposure days, 10 percent of the individuals in Group I had an absolute granulocyte level of 1000 per cubic millimeter or below. The lowest count observed during this period was 700 granulocytes/mm.[3]

Less striking fallout described as "mist-like" was observed on Ailinginae and Rongerik. Fallout was not visible on Utirik, which was contaminated to only a mild degree. The severity of the skin manifestations was roughly proportional to the amount of fallout observed.

Group	Fallout Observed	Skin Lesions and Epilation
Rongelap	Heavy (snowlike)	Extensive.
Ailinginae	Moderate (mistlike)	Less extensive.
Rongerik	Moderate (mistlike)	Slight.
Utirik	None	No skin lesions or epilation.

During The First 24–48 hours after exposure, about 25 percent of the Marshallese in the two higher exposure groups experienced itching and a burning sensation of the skin.

Skin lesions in the lesser exposed Ailinginae and Rongerik groups developed approximately one week after those in the Rongelap group, and were less severe and extensive. The Utirik group did not develop any lesions which could be attributed to irradiation of the skin. The incidence of ulcerating lesions in the different groups reflected the relative severity of the skin injury. Twenty percent of the Rongelap people developed ulcerative lesions while only five percent of the Ailinginae and none of the Rongerik people developed ulcerative lesions. Ninety percent of the Rongelap and Ailinginae groups developed lesions, compared to only forty percent of the Rongerik group. There were more lesions per individual in the Rongelap group than in the Ailinginae or Rongerik groups. A comparison of the incidence and time of appearance of epilation and neck lesions in the two groups is illustrated graphically in Figure 3.1.

a. *Shelter.* Those individuals who remained indoors or under the trees during the fallout period developed less severe lesions.

b. *Bathing.* Small children who went wading in the ocean developed fewer foot lesions. Most of the Americans, who were more aware of the danger of the fallout, took shelter in aluminum buildings, bathed and changed clothes and consequently developed only very mild beta lesions.

c. *Clothing.* A single layer of cotton material offered almost complete protection, as was demonstrated by the fact that lesions developed almost entirely on the exposed parts of the body.

3.54 Factors Favoring the Development of Lesions

a. *Areas of more profuse perspiration.* Lesions were more numerous in areas where perspiration is abundant such as the folds of the neck, axillae, and antecubital fossae.

b. *Delay in decontamination.* There was a delay of 1 or 2 days before satisfactory decontamination was possible.

Table 1.1—Exposed, and Control Unexposed Groups

Group Designation	Total Number in Group	Approximate Time of Commencement of Fallout	Time of Evacuation	Instrument Readings Used in Dose Calculations	Best Estimate of Total Gamma Dose in Air (r)
Group I.—Rongelap	64	H + 4 to 6 hrs.	H + 50 hrs. (16 people) H + 51 hrs. (48 people)	375 mr/hrs., H + 7 days	175
Group II.—Ailinginae	18	H + 4 to 6 hrs.	H + 58 hrs.	100 mr/hrs., H + 9 days	69
Group III.—Rongerik	28	H + 6.8 hrs.	H + 28.5 hrs. (8 men) H + 34 hrs. (20 men)	280 mr/hrs., H + 9 days	78
Group IV.—Utirik	157	H + 22 hrs.	Started at H + 55 hrs. Completed at H + 78 hrs.	40 mr/hrs., H + 8 days	14

Group	Composition	Fallout observed	Estimated gamma dose (rads)	Extent of skin lesions
Rongelap	64 Marshallese	Heavy (snowlike)	175	Extensive
Ailingnae	18 Marshallese	Moderate (mistlike)	69	Less extensive
Rongerik	28 Americans	Moderate (mistlike)	78	Slight
Utirik	157 Marshallese	None	14	No skin lesions or epilation

AD696959

DASA 2019-2

Proceedings:
SECOND INTERDISCIPLINARY CONFERENCE
ON SELECTED EFFECTS OF A GENERAL WAR

VOLUME II

This Conference was sponsored by the Defense Atomic Support Agency (Contract DASA 01-67-C-0024, NWER Subtask DB003) through the auspices of the New York Academy of Sciences Interdisciplinary Communications Program. It was held at Princeton, New Jersey, during 4-7 October 1967.

DASIAC Special Report 95
July 1969

SESSION II Wright H. Langham 45

LANGHAM: Fallout was predicted for the Trinity test in 1945 by the bomb phenologists, Hershfeider and McGee. Stafford Warren mounted evacuation teams and monitoring teams to cover the potential fallout area. We didn't have to evacuate anybody; we almost did. The arbitrary limit chosen for evacuation was an infinite life-time dose of 50 r. One family approached this limit, and there was much debate as to whether we should evacuate them or not. They weren't evacuated.

SESSION II Theodore B. Taylor 51

TAYLOR: I would like to interject something that you challenged, Staff. You said a moment ago, you can't hear it. Apropos of the Dog Shot, fallout was clearly audible. There were little beads of steel from the tower that condensed, and one heard this constant tinkle, tinkle of steel from the tower hitting the aluminum roofs and then rolling down the gutters and piling up in little piles on the ground.

76 Lin Root DASA 2019-2

ROOT: Mutual Security Agreement—after Korea. It was terribly important that Japan become a responsible member of the organization. The Yoshida cabinet was entirely favorable to the U.S. and it looked as if there would not be too much opposition. Then the fishermen arrived. Demonstrations flared up everywhere. You had the trade unions, three million strong, protesting. The cabinet tried to counteract the anti-American feeling but a tidal wave of anger inundated the country. It was just diminishing when Koboyama died. This was portrayed as a radiation death.

FREMONT-SMITH: This is the fisherman that had the transfusion and the hepatitis?

ROOT: Yes. Japanese doctors give very small blood transfusions, and Koboyama needed a great many.

15-kt Buffalo-1
(AWRE-T28/57, p. 26)
1 mm

WT-915 Castle-Bravo 15 megaton H-bomb test of 1 March 1954, which contaminated a Japanese tuna trawler and islanders

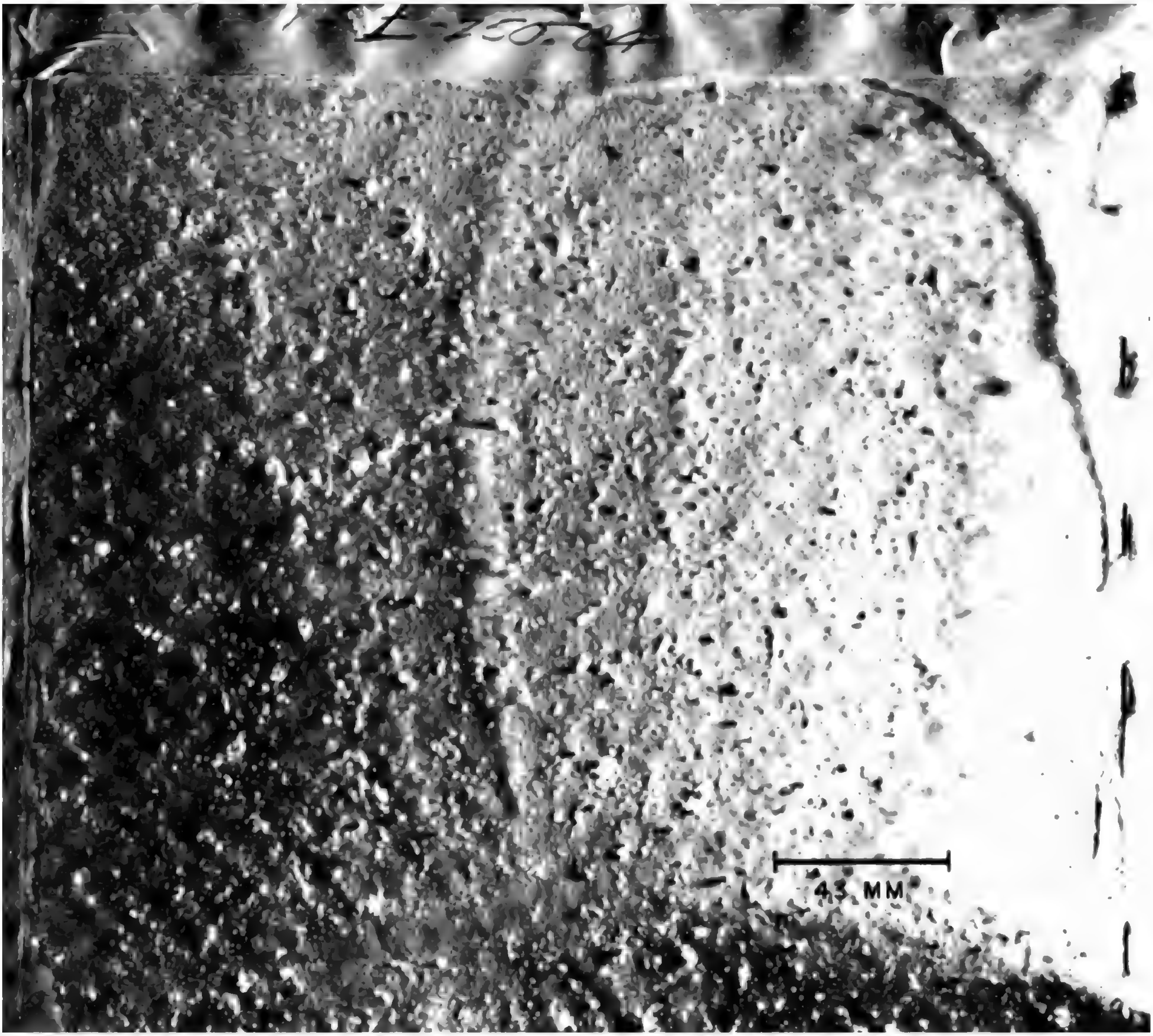


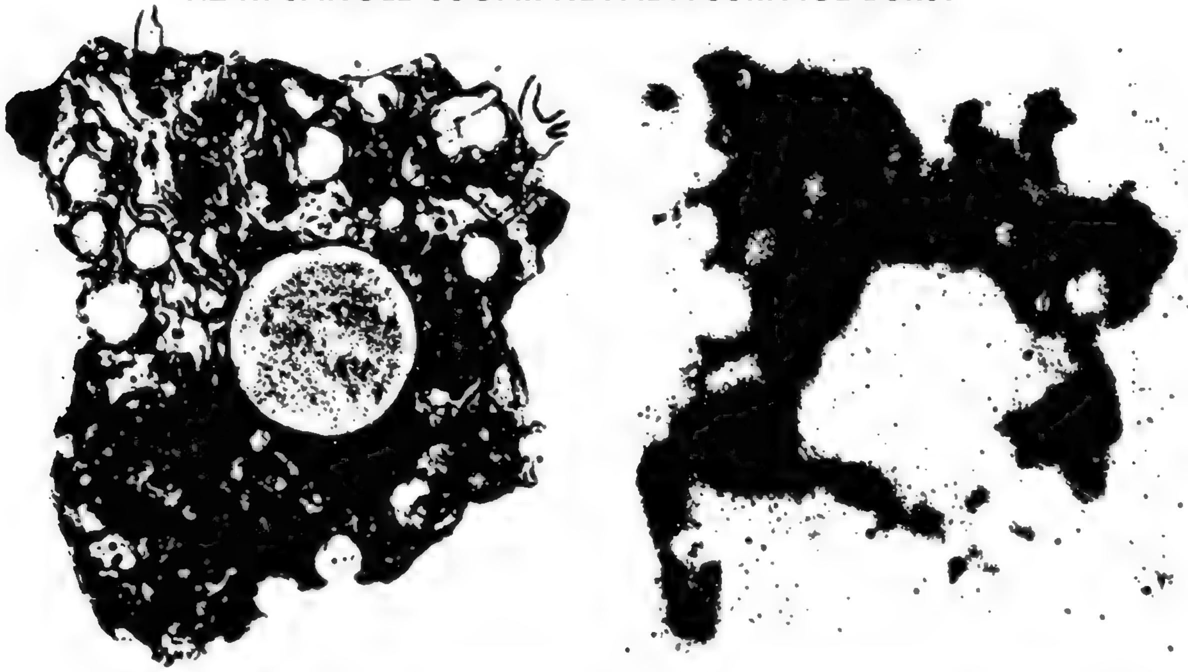
Fig. 5.10 Shot 1, Fallout Particulate, Station 250.04

This is a raft downwind in Bikini Lagoon, which received a land equivalent of 113 R/hr (1 hour reference gamma dose rate), according to Figures 2.2 and 6.1. Land equivalent dose rates were 7 times the raft dose rate in the lagoon.

According to Table 1 in Carl F. Miller's report USNRDL-466, 250.04 received 33.6 (mg/sq ft)/(R/hr at 1 hr) at 59.5 kft. Hence, 3.8 grams/sq ft.

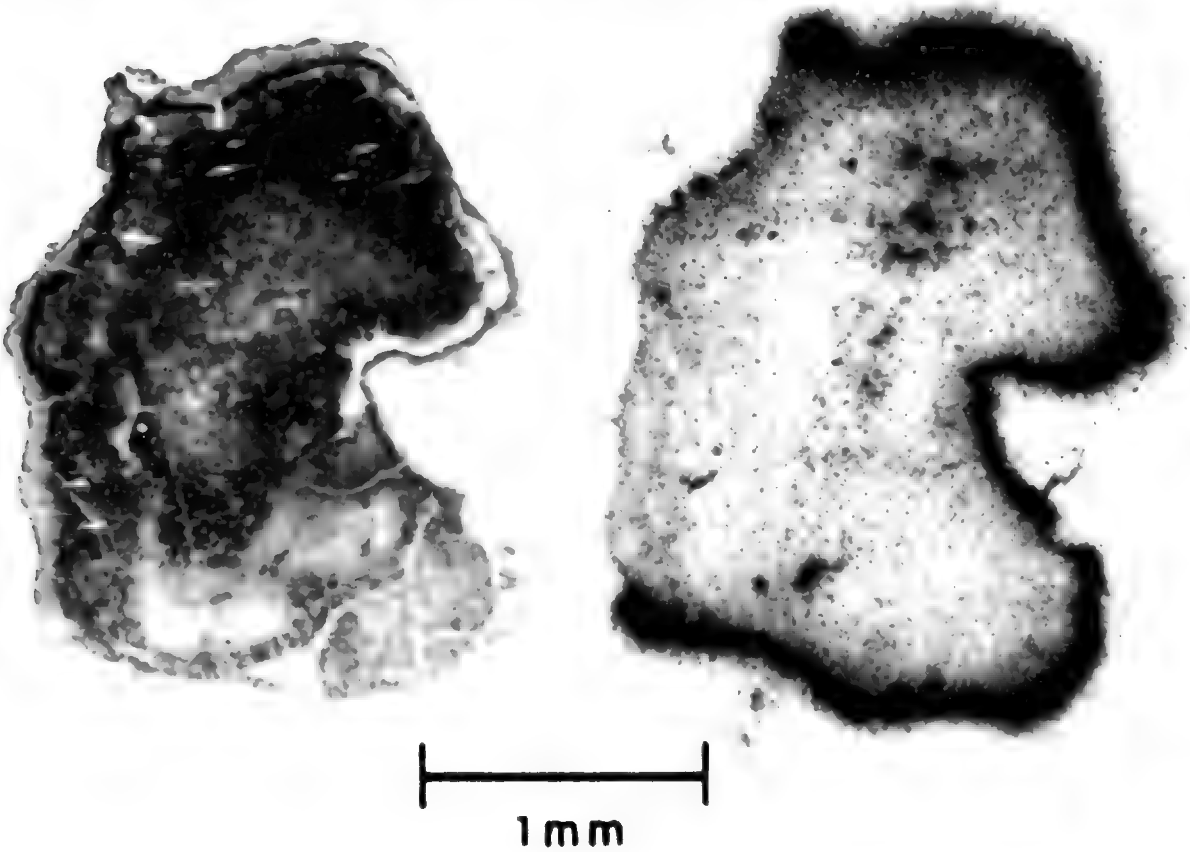
THIN SECTION AND RADIOGRAPH OF A FALLOUT PARTICLE FROM A SMALL-YIELD SURFACE SHOT AT THE NEVADA TEST SITE. THE PARTICLE IS A TRANSPARENT YELLOW-BROWN GLASS WITH MANY INCLUSIONS OF GAS BUBBLES AND UNMELTED MINERAL GRAINS. THE RADIOACTIVITY IS DISTRIBUTED IRREGULARLY THROUGHOUT THE GLASS PHASE OF THE PARTICLE

1.2 KT JANGLE-SUGAR NEVADA SURFACE BURST

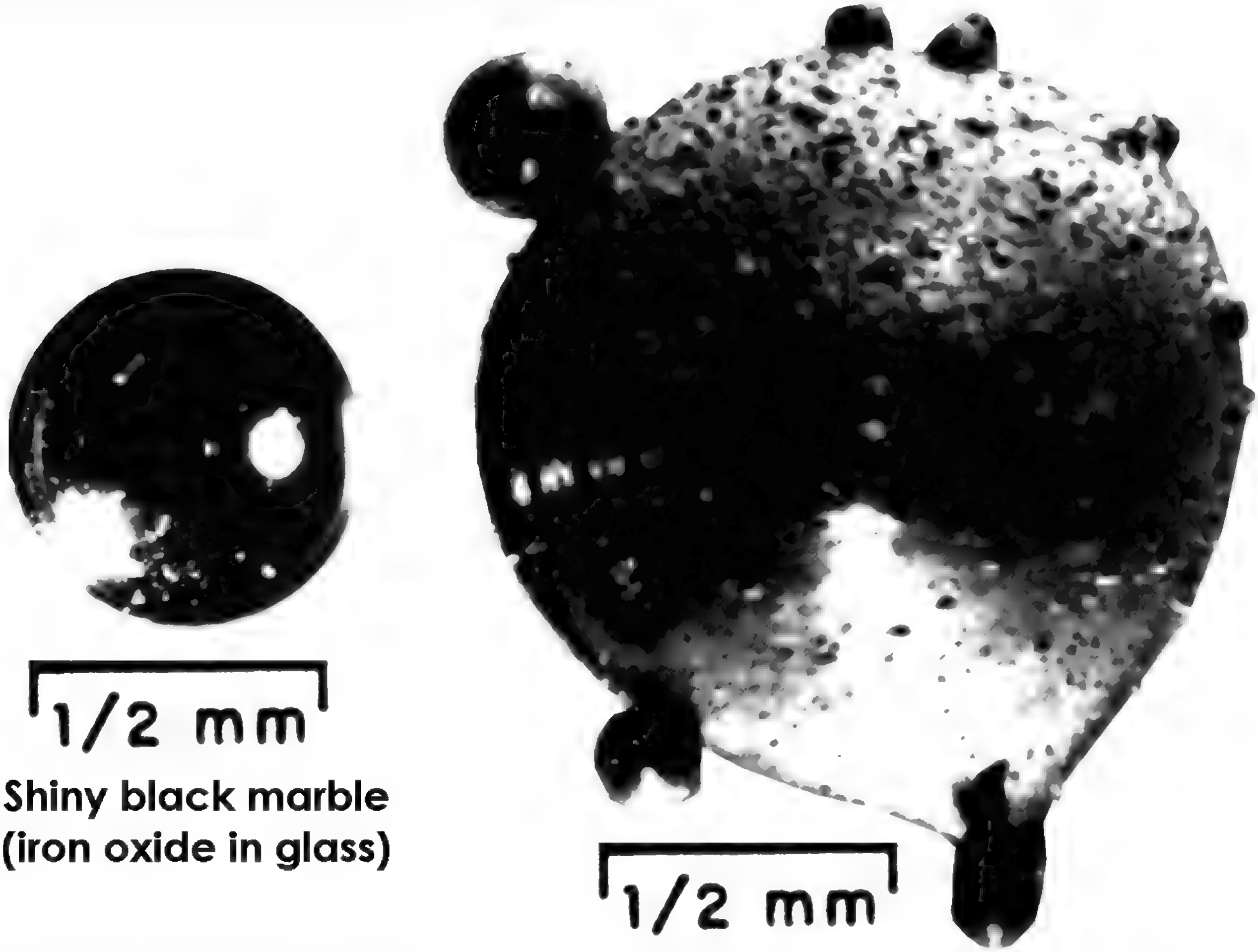


C.E. Adams, et al. The Nature of Individual Radioactive Particles. I. Surface and Underground A.B.D. Particles From Operation JANGLE. U.S. Naval Radiological Defense Laboratory Report, USNRDL-374, November 28, 1952

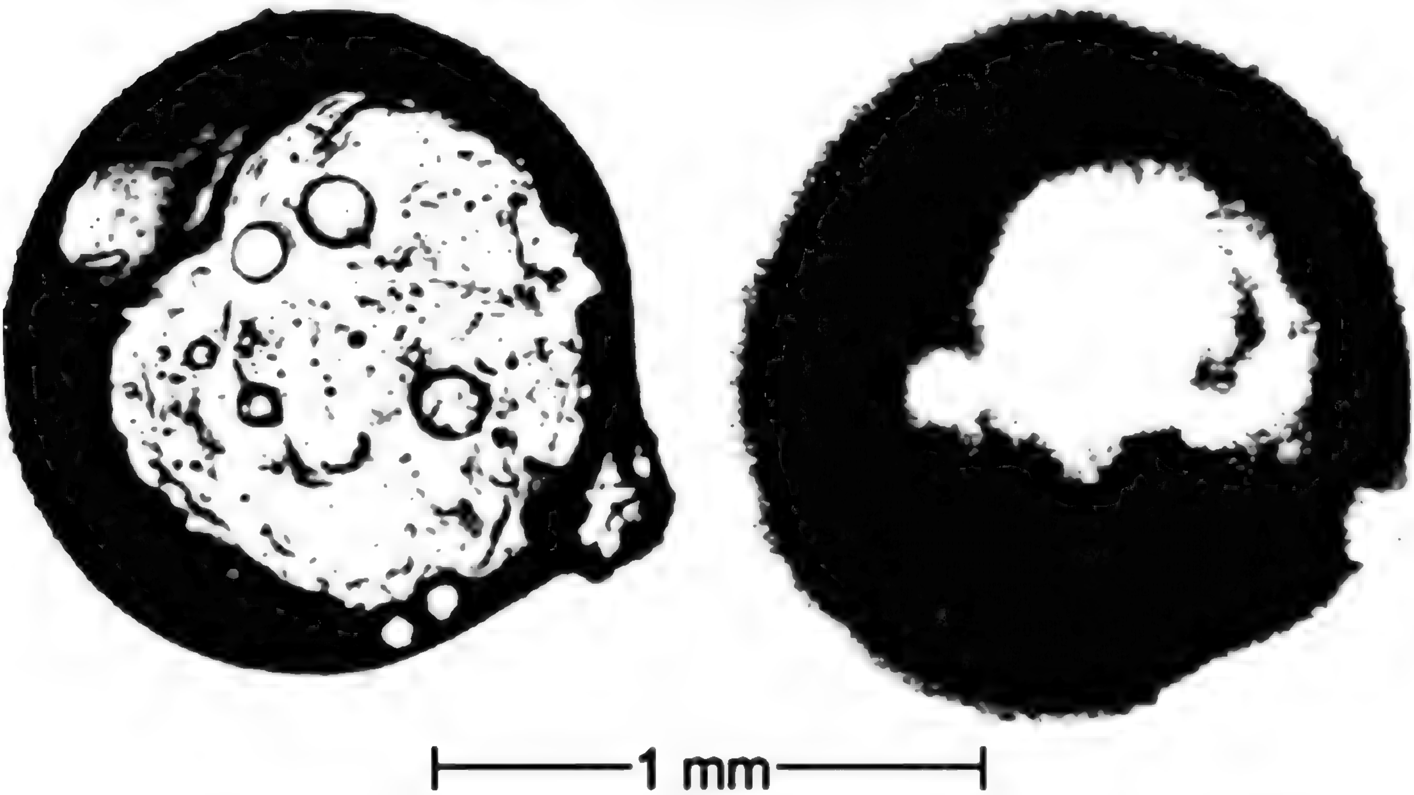
THIN SECTION AND RADIOGRAPH OF AN ANGULAR FALLOUT PARTICLE FROM A LARGE-YIELD SURFACE SHOT AT THE ENIWETOK PROVING GROUNDS. THIS PARTICLE IS COMPOSED ALMOST ENTIRELY OF CALCIUM HYDROXIDE WITH A THIN OUTER LAYER OF CALCIUM CARBONATE. THE RADIOACTIVITY HAS COLLECTED ON THE SURFACE AND HAS DIFFUSED A SHORT DISTANCE INTO THE PARTICLE



TWO FALLOUT PARTICLES FROM A TOWER SHOT AT THE NEVADA TEST SITE. THE PARTICLE ON THE LEFT IS A PERFECT SPHERE WITH A HIGHLY GLOSSY SURFACE; THE ONE ON THE RIGHT HAS MANY PARTIALLY-ASSIMILATED SMALLER SPHERES ATTACHED TO ITS SURFACE. BOTH PARTICLES ARE BLACK AND MAGNETIC AND HAVE A SUPERFICIAL METALLIC APPEARANCE.

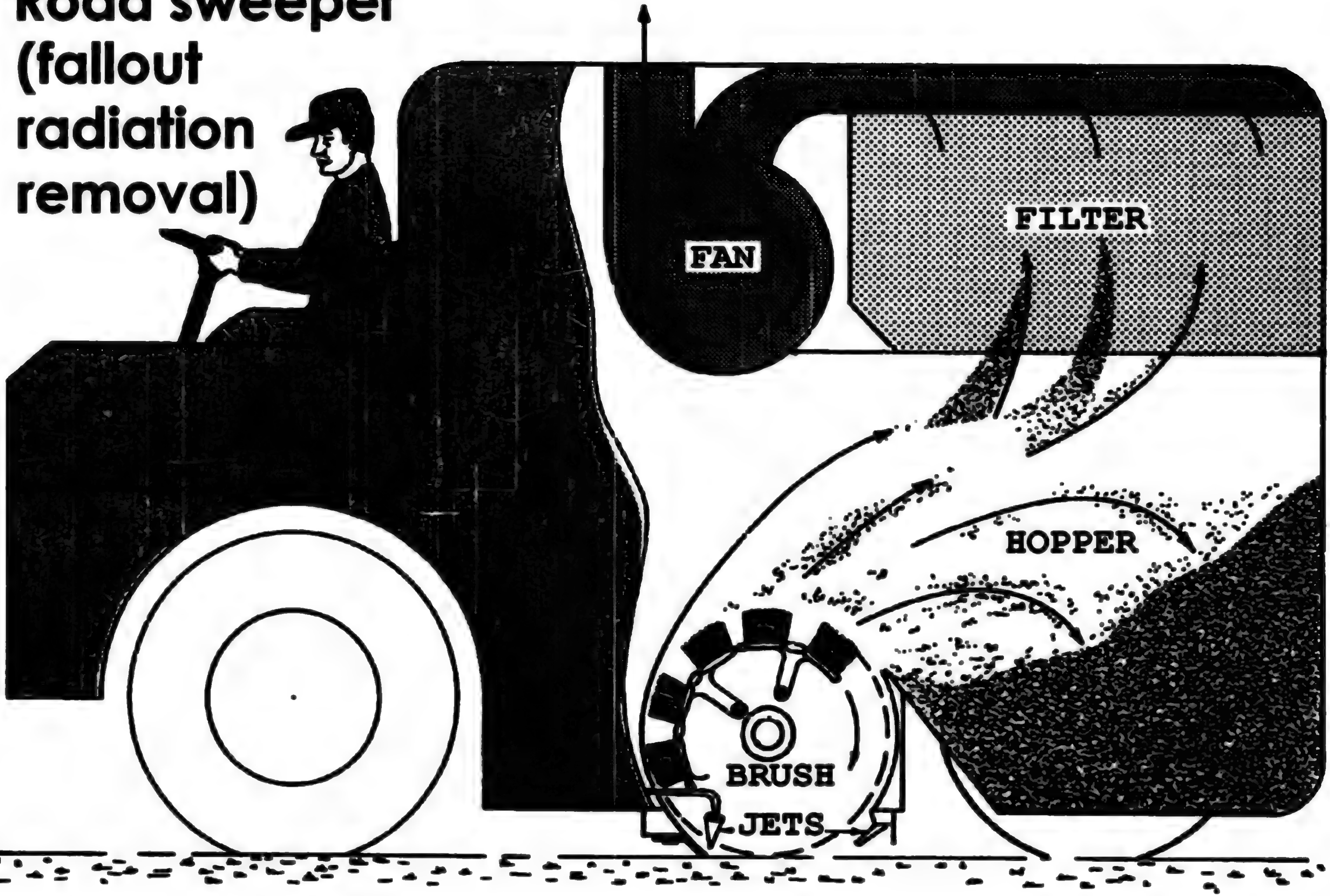


THIN SECTION AND RADIOGRAPH OF A FALLOUT PARTICLE FROM A MODERATE-YIELD TOWER SHOT AT THE NEVADA TEST SITE. THIS PARTICLE IS COMPOSED OF A TRANSPARENT GLASS CORE WITH A DARKLY COLORED IRON OXIDE GLASS OUTER ZONE. MOST OF THE RADIOACTIVITY IS CONCENTRATED IN THE OUTER ZONE



C.E. Adams. The Nature of Individual Radioactive Particles. IV. Fallout Particles From A.B.D. of Operation UPSHOT-KNOTHOLE. U.S. Naval Radiological Defense Laboratory Report, USNRDL-440, February 24, 1954

Road sweeper (fallout radiation removal)



USNRDL-TR-1049
28 July 1966

AD 641 480

REMOVAL OF SIMULATED FALLOUT FROM ASPHALT STREETS BY FIREHOSING TECHNIQUES

by

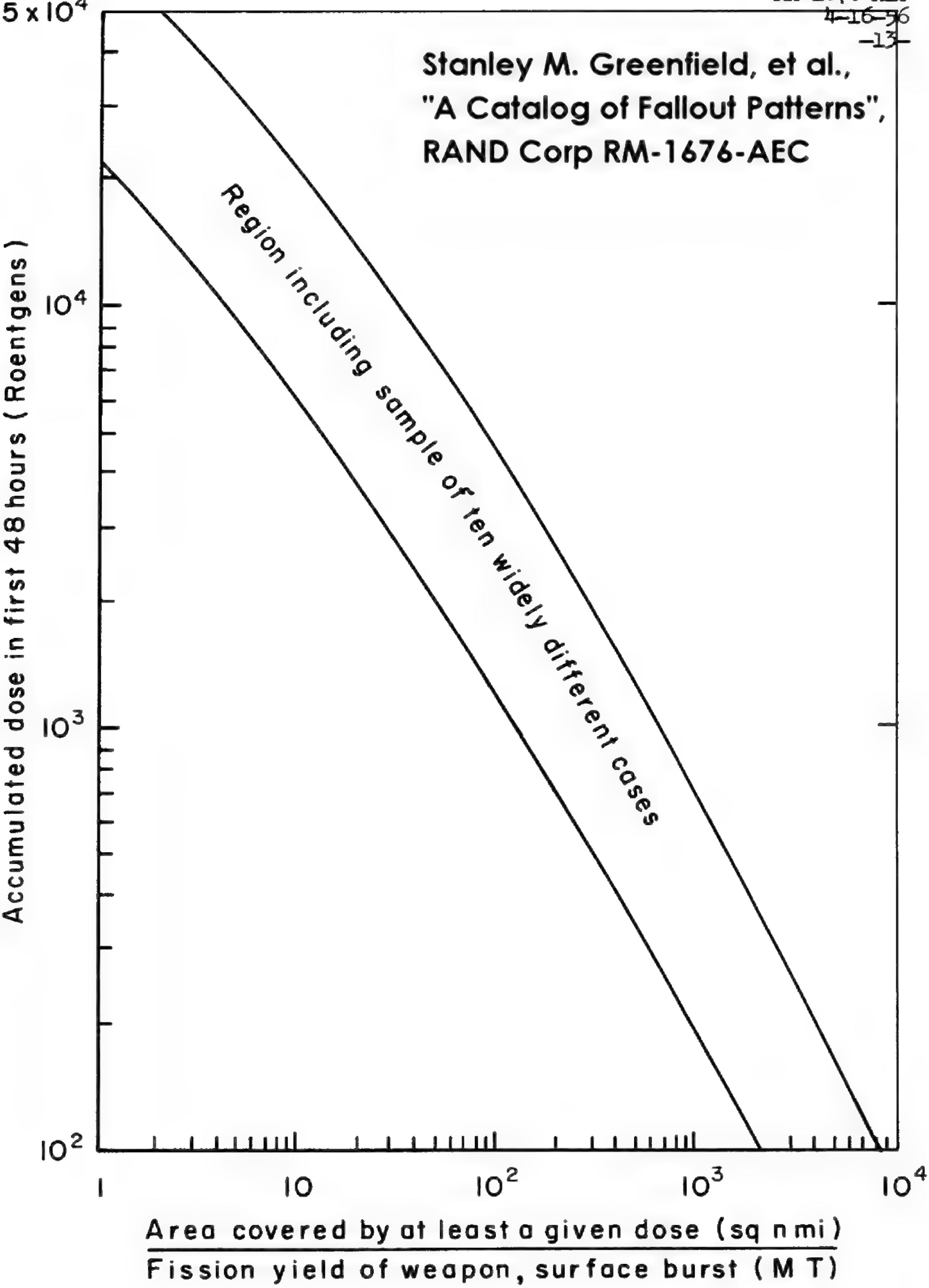
L.L. Wiltshire
W. L. Owen

In general, removal effectiveness improves with increased particle size range and increased mass loading. For the expenditure of an effort of 4 nozzle-minutes (12 man-minutes) per 10^3 ft^2, results ranged as follows:

Particle Size Range (μ)	Nominal Mass Loading (g/ft^2)	Removal Effectiveness (Residual Fraction)
44 - 88	4.0	0.16
	24.0	0.07
350 - 700	4.0	0.005
	24.0	0.003

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO · CALIFORNIA 94135

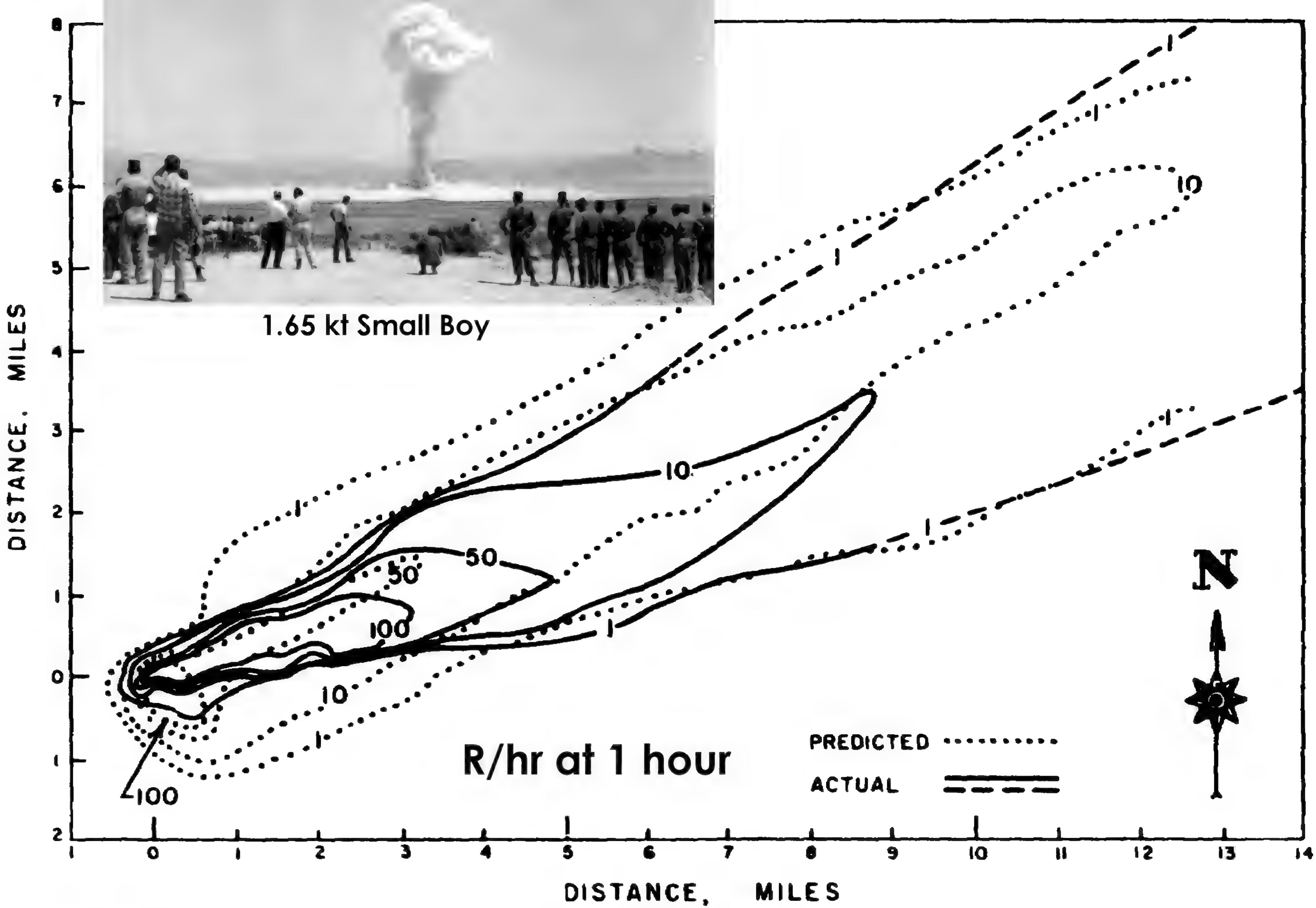


Approximate scaling relationship between 48-hr dose rate and normalized area

AD-A995490
POR-2266 (WT-2266)

TABLE 4.1 AREAS ENCLOSED BY DOSE RATE CONTOURS

Contour Dose Rate, I	Area Within Contour			
	0.018 kt	0.022 kt	0.5 kt	1.65 kt
	Little Feller I	Little Feller II	Johnie Boy	Small Boy
r/hr	mi^2	mi^2	mi^2	mi^2
0.5	0.33	0.827	-	109.83
1.0	0.208	0.469	33.097	61.63
5.0	-	0.070	-	-
10.0	0.032	0.045	3.924	9.057
20.0	-	0.019	-	-
50.0	-	-	0.536	2.954
100.0	0.00478	0.005	0.214	1.200
200.0	-	-	-	0.285
1,000.0	-	-	0.0917	0.092
2,000.0	-	-	-	0.01665
10,000.0	-	-	0.0161	-
17,000.0	-	-	0.00537	-



AD–A995490
POR-2266 (WT-2266)

Figure 4.13 Comparison of Ford Instrument Company prediction with observed Small Boy pattern.

Small Boy
14 Jul 1962
TYPE OF BURST AND PLACEMENT:
Tower, over Nevada soil
CLOUD TOP HEIGHT: 19,000 ft MSL
SITE ELEVATION: 3078 ft MSL

Altitude (MSL)	H+5 Minutes Direction	Speed
feet	degrees	mph
3,078	135	2.3
4,000	300	1.2
5,000	310	1.2
6,000	330	2.3
7,000	280	2.3
8,000	250	6.9
9,000	240	13.8
10,000	240	18.4
12,000	240	9.2
14,000	240	9.2
15,000	-	-
16,000	240	9.2
18,000	280	16.1
20,000	280	28.8

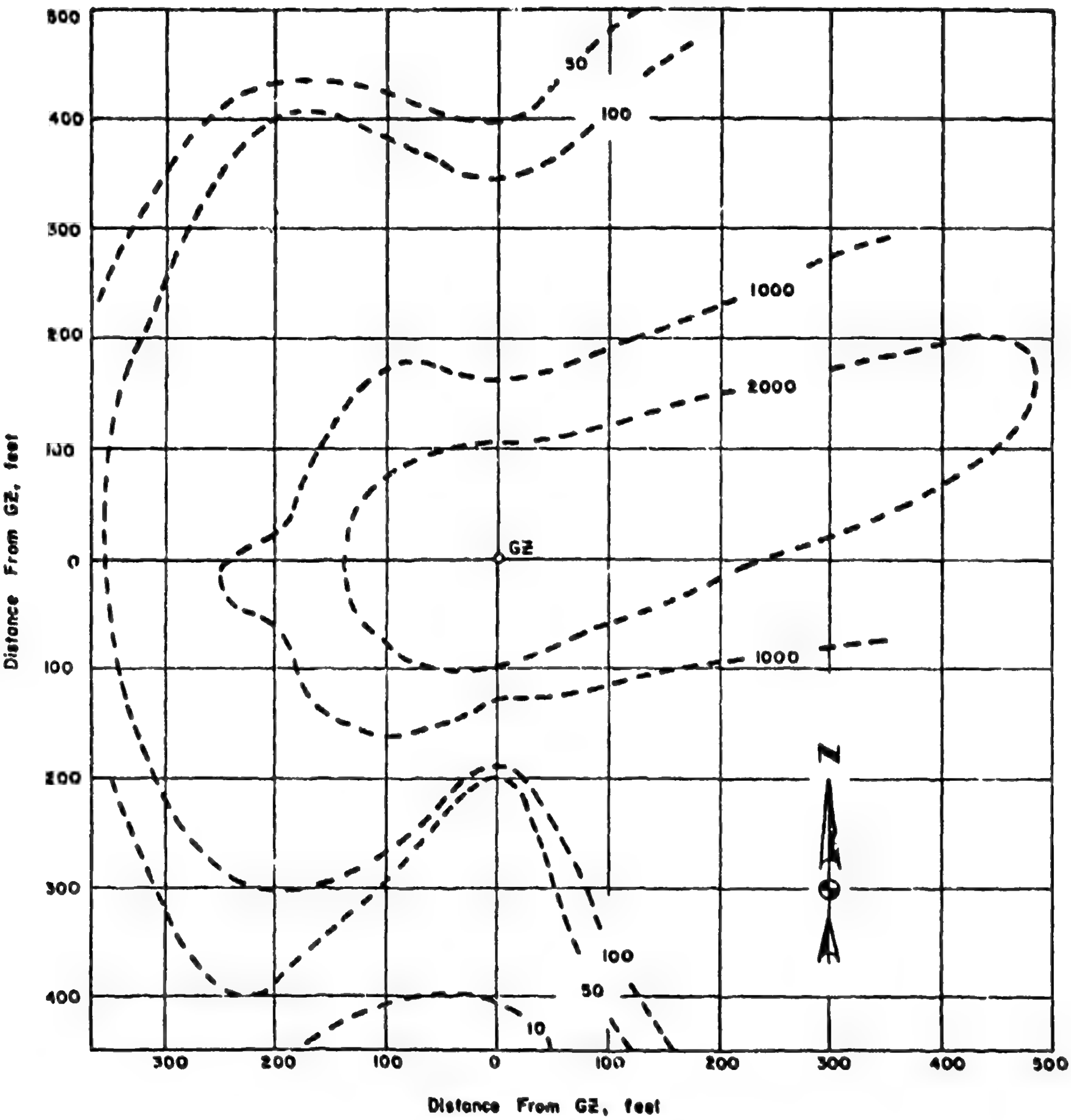
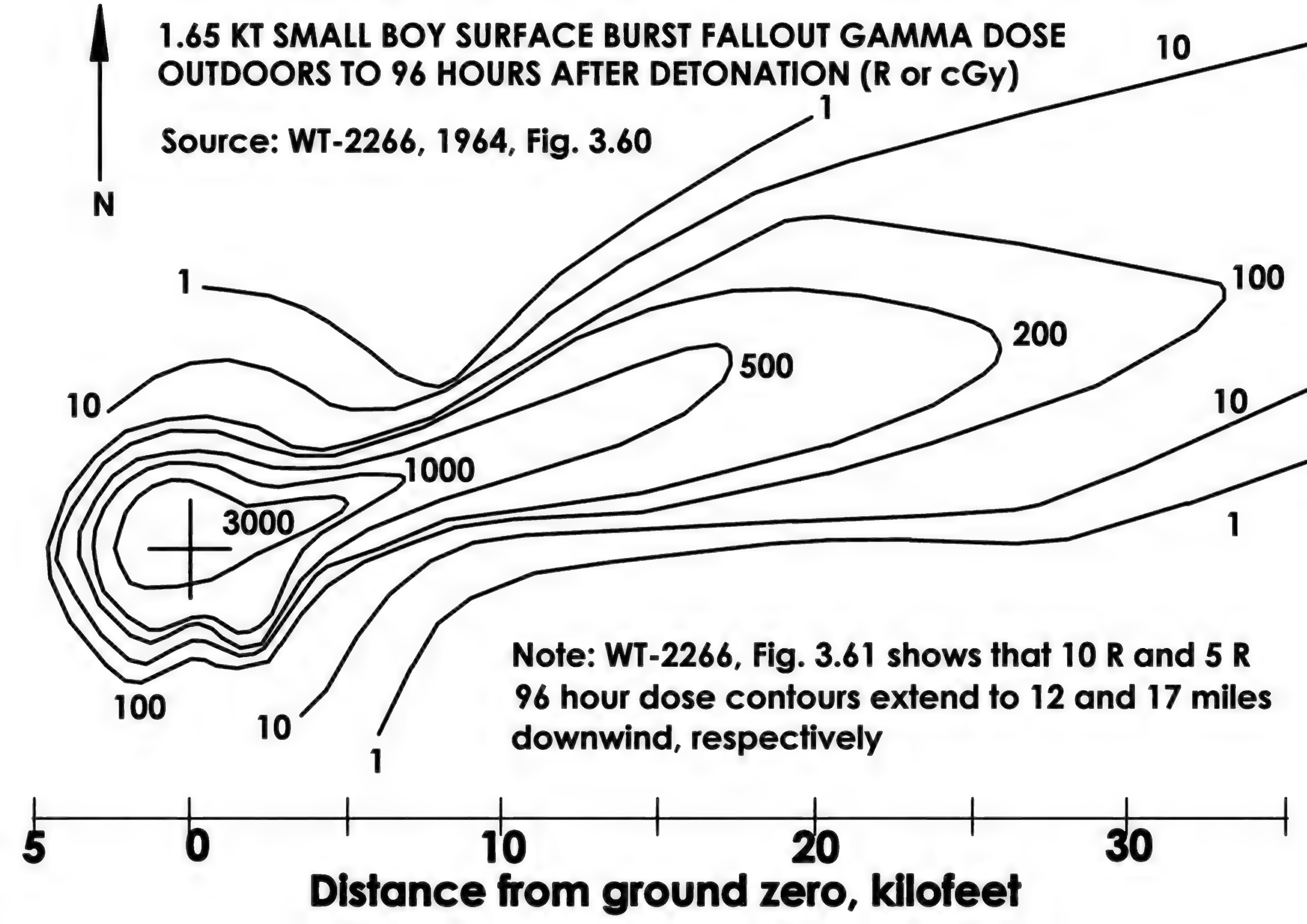
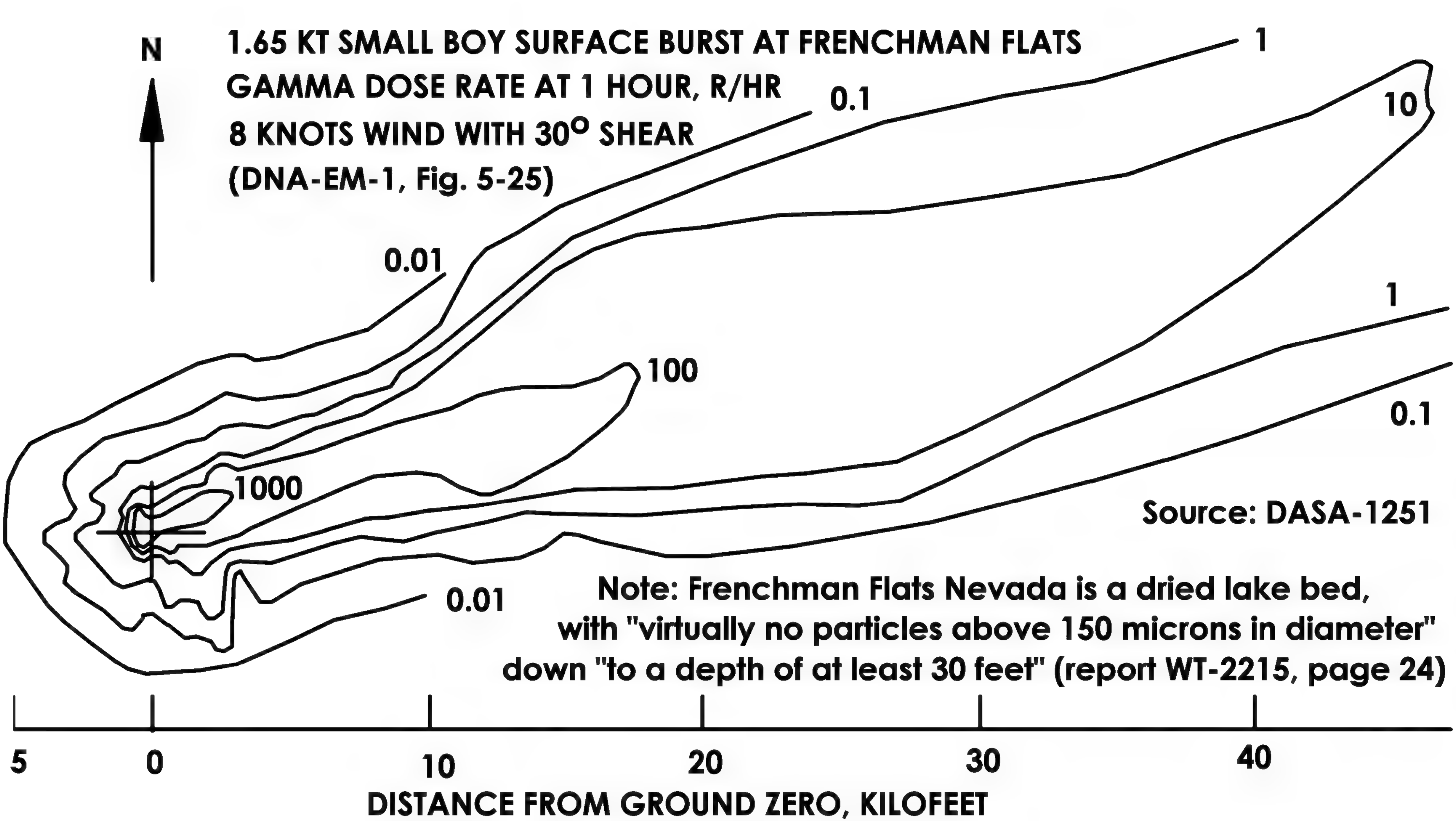


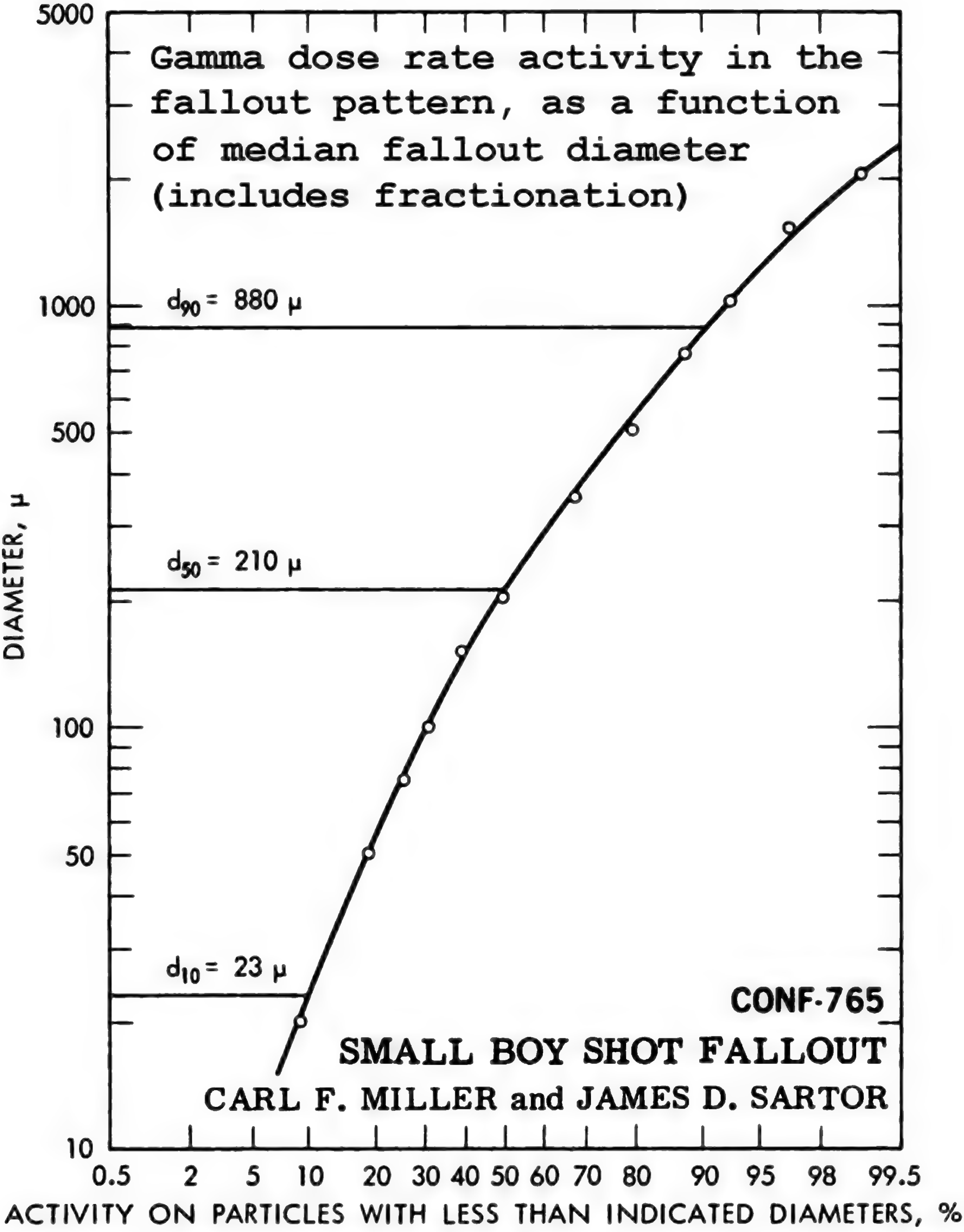
Figure 329. OPERATION SUNBEAM - Small Boy GZ area contours in R/hr at H+1 hour

The contours were corrected to H+1 hour using a decay constant of 1.27.

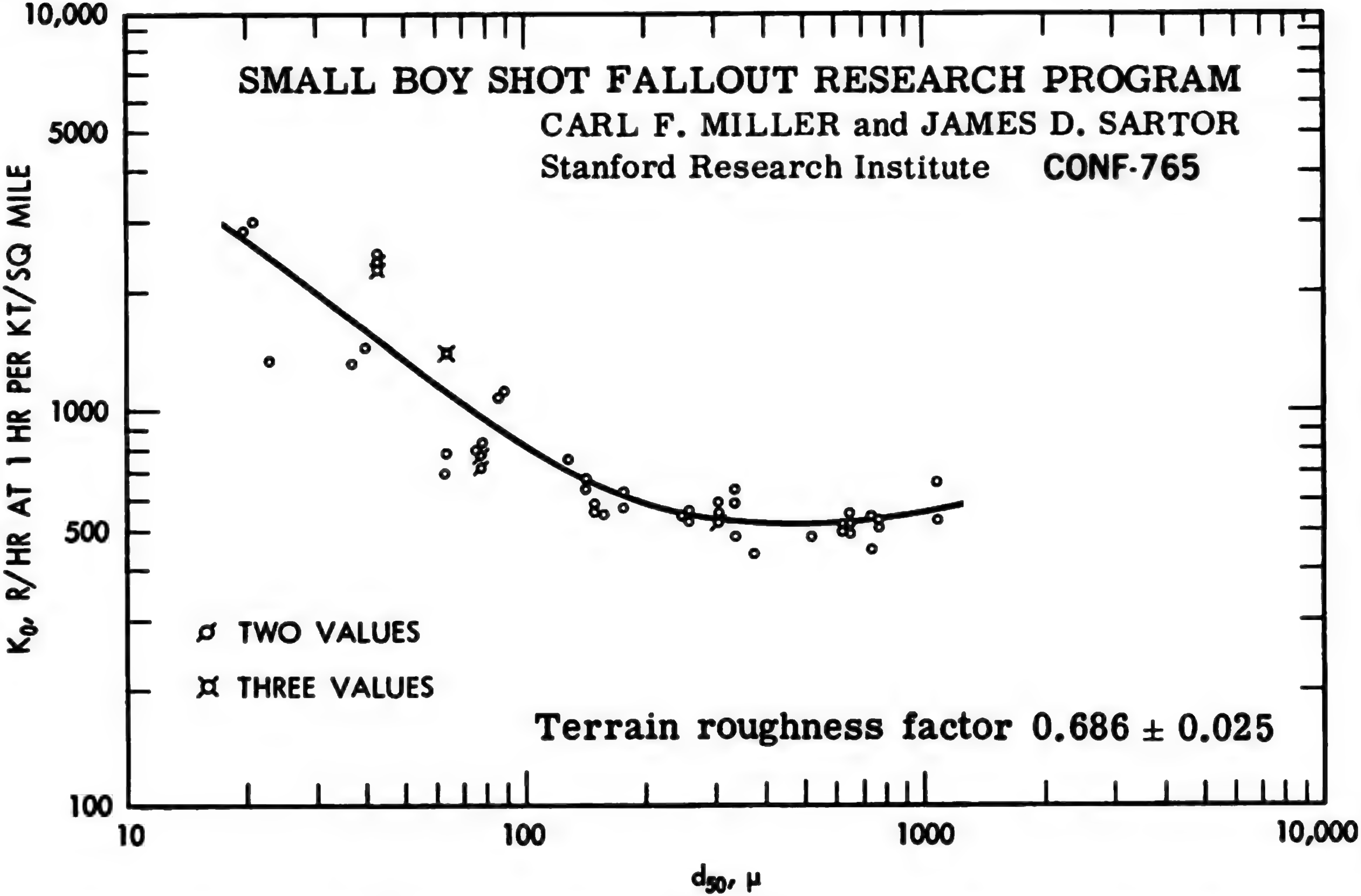

1.65 KT SMALL BOY SURFACE BURST FALLOUT GAMMA DOSE OUTDOORS TO 96 HOURS AFTER DETONATION (R or cGy)
Source: WT-2266, 1964, Fig. 3.60
N
10
1
1
100
200
500
10
10
1000
3000
1
100
10
1
Note: WT-2266, Fig. 3.61 shows that 10 R and 5 R 96 hour dose contours extend to 12 and 17 miles downwind, respectively
5
0
10
20
30
Distance from ground zero, kilofeet



N
1.65 KT SMALL BOY SURFACE BURST AT FRENCHMAN FLATS
GAMMA DOSE RATE AT 1 HOUR, R/HR
8 KNOTS WIND WITH 30° SHEAR
(DNA-EM-1, Fig. 5-25)
1
0.1
10
0.01
1
100
0.1
1000
Source: DASA-1251
0.01
Note: Frenchman Flats Nevada is a dried lake bed,
with "virtually no particles above 150 microns in diameter"
down "to a depth of at least 30 feet" (report WT-2215, page 24)
5
0
10
20
30
40
DISTANCE FROM GROUND ZERO, KILOFEET



Gamma dose rate activity in the fallout pattern, as a function of median fallout diameter (includes fractionation)
5000
1000
500
100
50
10
DIAMETER, μ
d90 = 880 μ
d50 = 210 μ
d10 = 23 μ
0.5
2
5
10
20
30
40
50
60
70
80
90
95
98
99.5
ACTIVITY ON PARTICLES WITH LESS THAN INDICATED DIAMETERS, %
CONF-765
SMALL BOY SHOT FALLOUT
CARL F. MILLER and JAMES D. SARTOR



Fractionation effect (factor including terrain shielding)

CONF-765

EARLY FOOD-CHAIN KINETICS OF RADIONUCLIDES FOLLOWING CLOSE-IN FALLOUT FROM A SINGLE NUCLEAR DETONATION

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University of California at Los Angeles, Los Angeles, California

ABSTRACT

Radiochemical and statistical analyses indicated highly significant correlations between estimates of gamma dose rates and maximum concentrations of ^{89}Sr or ^{131}I in plant samples and in the stomach contents, bone ash, or thyroids of rabbits collected between 15 and 110 miles from ground zero.

Table 1 — AVERAGE GAMMA DOSE RATES, R_0, AND AVERAGE CONCENTRATIONS OF ^{89}Sr IN PLANT SAMPLES AND IN THE BONE ASH OF RABBITS COLLECTED FROM THE SEDAN FALLOUT FIELD

Study areas	Initial gamma dose rates			Days after detonation	Plant samples, pc ^{89}Sr/g (dry)			Rabbit bone ash, pc ^{89}Sr/g (dry)		
	$\bar{x}$	$s\bar{x}$	n		$\bar{x}$	$s\bar{x}$	n	$\bar{x}$	$s\bar{x}$	n
				5	1436	±32%	20	863	±29%	20
All areas	17.5	±30%	20	15	909	±37%	20	1680	±38%	20
R_0 = mr/hr at 3 ft at H + 24.				30	544	±40%	20	2097	±30%	20
				60	313	±32%	20	1389	±34%	20

$\bar{x}$ = mean, $s\bar{x}$ = standard error expressed as a percentage of the mean, and n = number of samples.

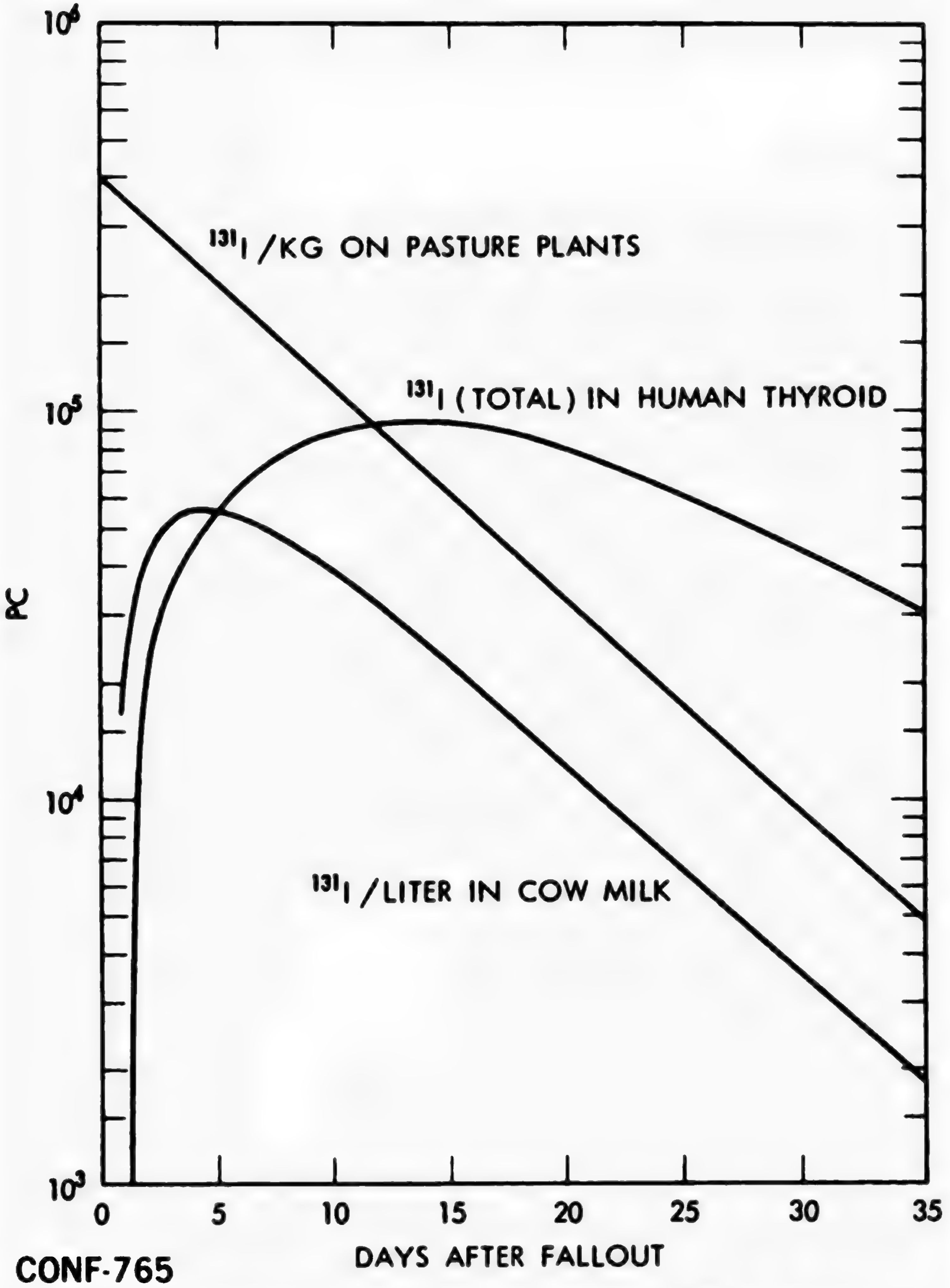
Table 2 — AVERAGE CONCENTRATIONS OF ^{131}I IN PLANT SAMPLES AND IN THE THYROIDS OF RABBITS COLLECTED FROM THE SEDAN FALLOUT FIELD

Study areas	Days after detonation	Plant samples, pc ^{131}I/g (dry)			Rabbit thyroids, nc ^{131}I per thyroid		
		$\bar{x}$	$s\bar{x}$	n	$\bar{x}$	$s\bar{x}$	n
All areas	5	3606	±40%	20	221	±28%	19
	15	984	±40%	20	74	±36%	20
	30	113	±27%	20	12	±50%	20

$\bar{x}$ = mean, $s\bar{x}$ = standard error expressed as a percentage of the mean, and n = number of samples.

Our estimates of effective half-lives on plants in the Sedan fallout field, 18 days for ^{89}Sr and 5.0 to 5.5 days for ^{131}I, indicate environmental half-lives (i.e., half-time rates of loss due to all causes other than radioactive decay) of approximately 28 days for ^{89}Sr and 15 days for ^{131}I. Since there was little or no rain in the area of the Sedan fallout field during the period of this study, the environmental half-life of ^{89}Sr on plants can be attributed primarily to wind action that removed particles from foliage or foliage from plants. The shorter environmental half-life of ^{131}I on plants may reflect the combined effects of wind action and sublimation.[1,2]

1. W. E. Martin, Losses of Sr^{90}, Sr^{89}, and I^{131} from Fallout Contaminated Plants, *Radiation Botany*, in press.
2. W. E. Martin, Loss of I^{131} from Fallout-contaminated Vegetation, *Health Phys.*, *9:* 1141-1148 (1963).



CONF-765

Fig. 8—Hypothetical concentrations of ^{131}I on pasture plants, in cow milk, and in human thyroids following environmental contamination by a single fallout event.

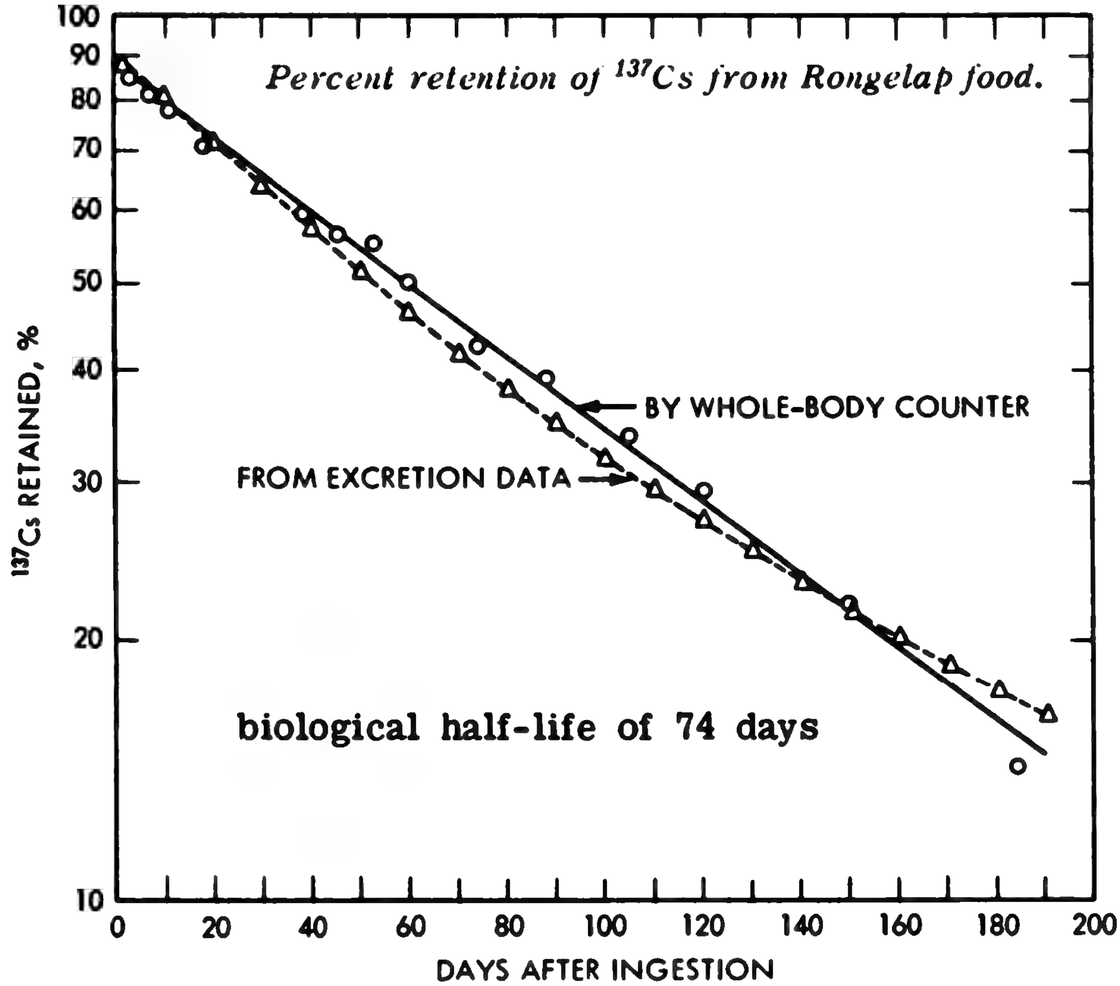
Table 6—SUMMARY OF HYPOTHETICAL VALUES THAT, IF INDICATED BY MEASUREMENTS MADE AFTER ENVIRONMENTAL CONTAMINATION BY A SINGLE FALLOUT EVENT, WOULD IMPLY TOTAL DOSES OF 0.5 REM TO THE SKELETONS OR THYROIDS OF INFANTS CONSUMING 1 LITER OF MILK PER DAY

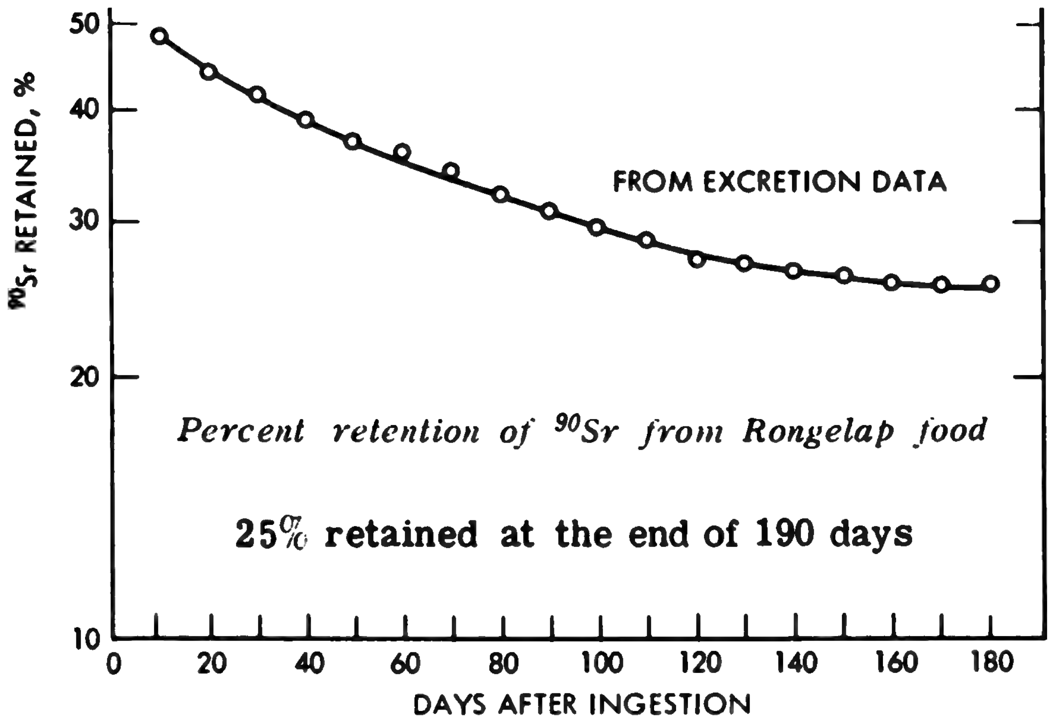
Hypothetical values	^{89}Sr	^{131}I
Initial concentrations on pasture plants, P_0	61.0 pc/g	13.7 pc/g
Maximum concentrations in milk, M_t	4500 pc/liter	1850 pc/liter
Time after fallout, t_{max}	8 days	4 days
Total intake (to $t = \infty$)	1.60×10^5 pc	2.63×10^4 pc
Maximum concentration in human tissue, H_t	27 pc/g†	1580 pc/g†
Time after fallout, t_{max}	50 days	15 days
Total dose (at $t = \infty$)	0.5 rem†	0.5 rem†

†Based on a 700-g skeleton or a 2.0-g thyroid.

CESIUM-137 AND STRONTIUM-90 RETENTION FOLLOWING AN ACUTE INGESTION OF RONGELAP FOOD

EDWARD P. HARDY, Jr.,* JOSEPH RIVERA,* and ROBERT A. CONARD†
*Health and Safety Laboratory, U. S. Atomic Energy Commission, New York, New York, and †Brookhaven National Laboratory, Upton, New York.





Survival of Food Crops and Livestock in the Event of Nuclear War

Proceedings of a symposium held at
Brookhaven National Laboratory
Upton, Long Island, New York
September 15–18, 1970

Sponsored by
Office of Civil Defense
U. S. Atomic Energy Commission
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Editors

David W. Bensen
Office of Civil Defense
Arnold H. Sparrow
Brookhaven National Laboratory

December 1971

U. S. ATOMIC ENERGY COMMISSION Office of Information Services

THE SIGNIFICANCE OF LONG-LIVED NUCLIDES AFTER A NUCLEAR WAR

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Agricultural Research Council, Letcombe Laboratory, Wantage, Berkshire, England

ABSTRACT

The radiation doses from the long-lived nuclides ^{90}Sr and ^{137}Cs, to which the surviving population might be exposed after a nuclear war, are considered using a new evaluation of the transfer of ^{90}Sr into food chains.

As an example, it is estimated that, in an area where the initial deposit of near-in fallout delivered 100 R/hr at 1 hr and there was subsequent worldwide fallout from 5000 Mt of fission, the dose commitment would be about 2 rads to the bone marrow of the population and 1 rad to the whole body. Worldwide fallout would be responsible for the major part of these doses.

In view of the possible magnitude of the doses from long-lived nuclides, the small degree of protection that could be provided against them, and the considerable strain any such attempt would impose on the resources of the community, it seems unrealistic to consider remedial measures against doses of this magnitude. Civil-defense measures should be directed at mitigating the considerably higher doses that short-lived nuclides would cause in the early period.

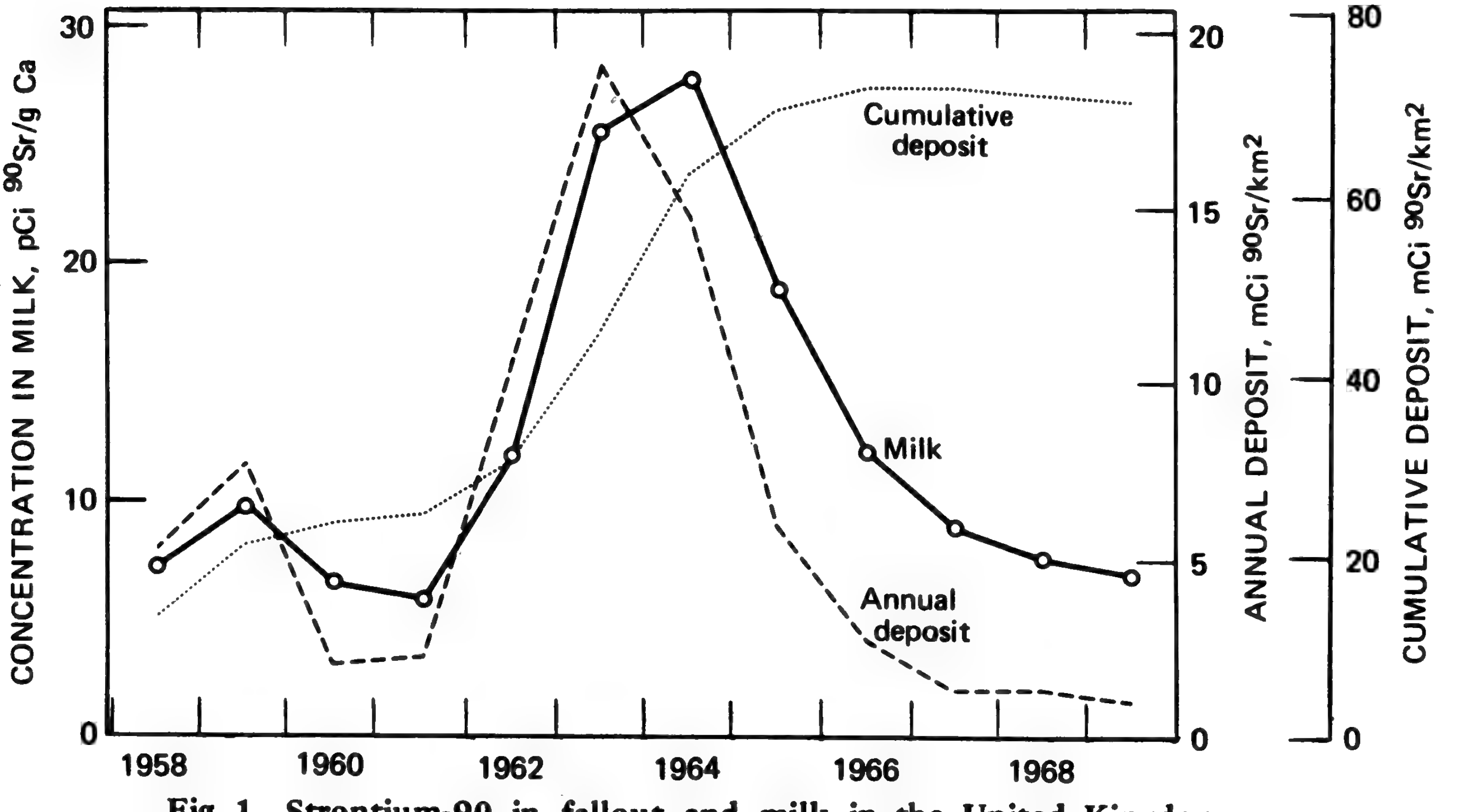


Fig. 1 Strontium-90 in fallout and milk in the United Kingdom

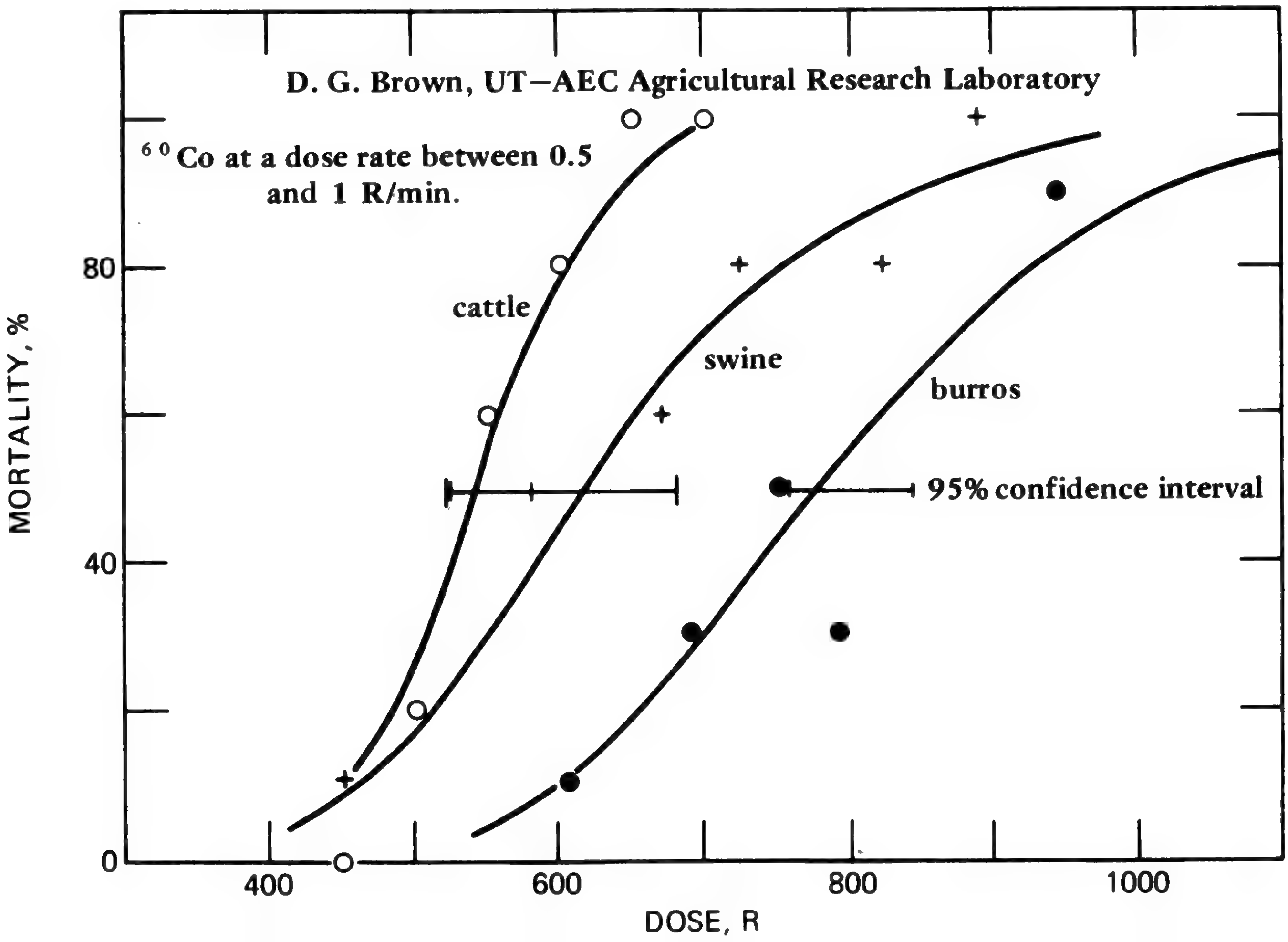
RADIATION EFFECTS ON FARM ANIMALS: A REVIEW

M. C. BELL
UT–AEC Agricultural Research Laboratory, Oak Ridge, Tennessee

ABSTRACT

Hematopoietic death would predominate in food-producing animals exposed to gamma radiation under fallout conditions leaving animal survivors. Gamma-radiation doses of about 900 R would be lethal to 50% of poultry, and about half this level would be lethal for cattle, sheep, and swine. Grazing cattle and sheep would suffer most from combined radiation effects of skin-beta and ingested-beta radioactivity plus the whole-body gamma effects. The $LD_{50/60}$ for combined effects in ruminants is estimated to be at a gamma exposure of around 200 R in an area where the forage retention is 7 to 9%.

Either external parasites or severe heat loss could be a problem in skin irradiated animals. Contrary to early reports, bacterial invasion of irradiated food-producing animals does not appear to be a major problem. Productivity of survivors of gamma radiation alone would not be affected, but, in an area of some lethality, the productivity of surviving grazing livestock would be severely reduced owing to anorexia and diarrhea. Sheltering animals and using stored feed as countermeasures during the first few days of livestock exposure provide much greater protection than shielding alone.



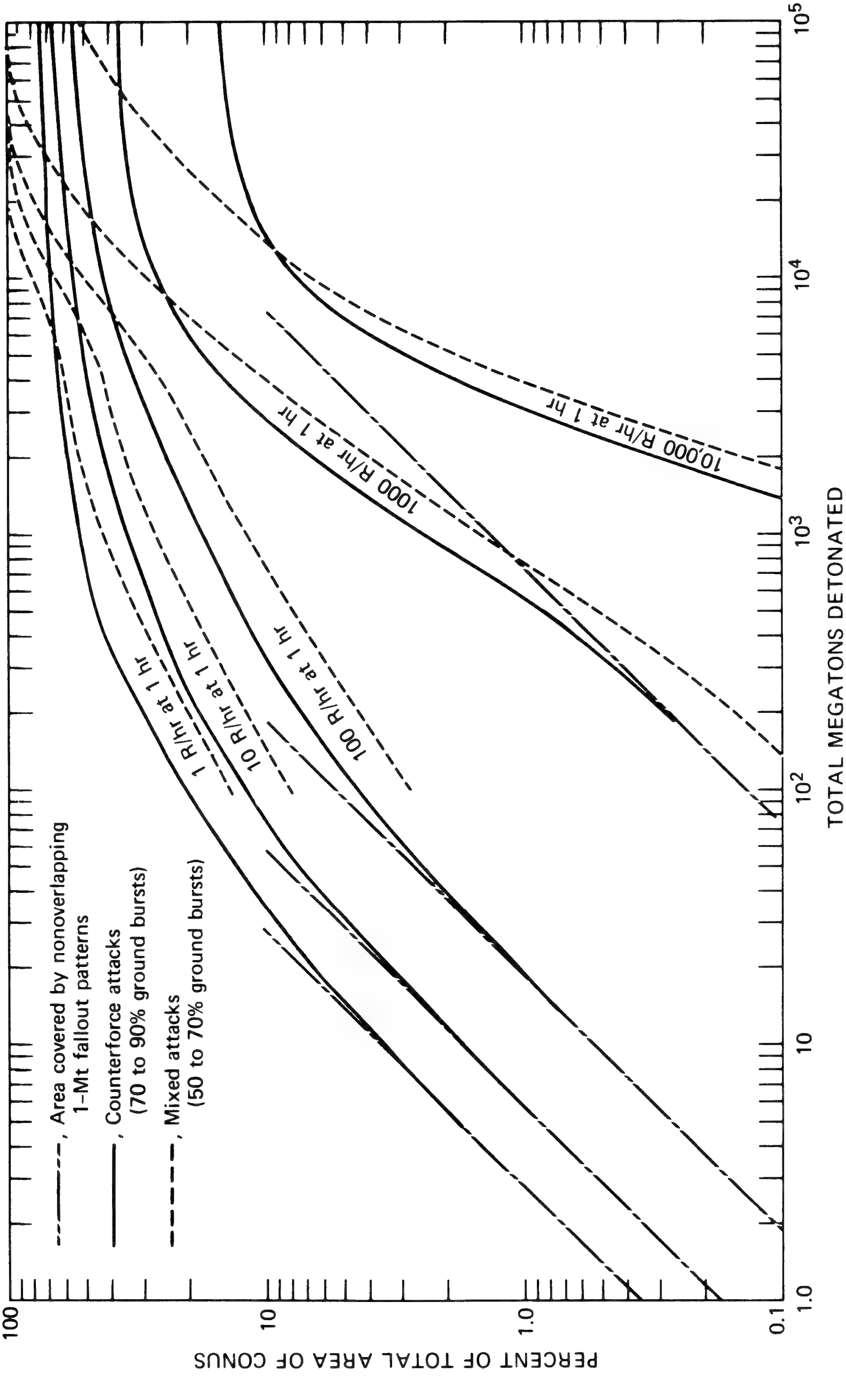
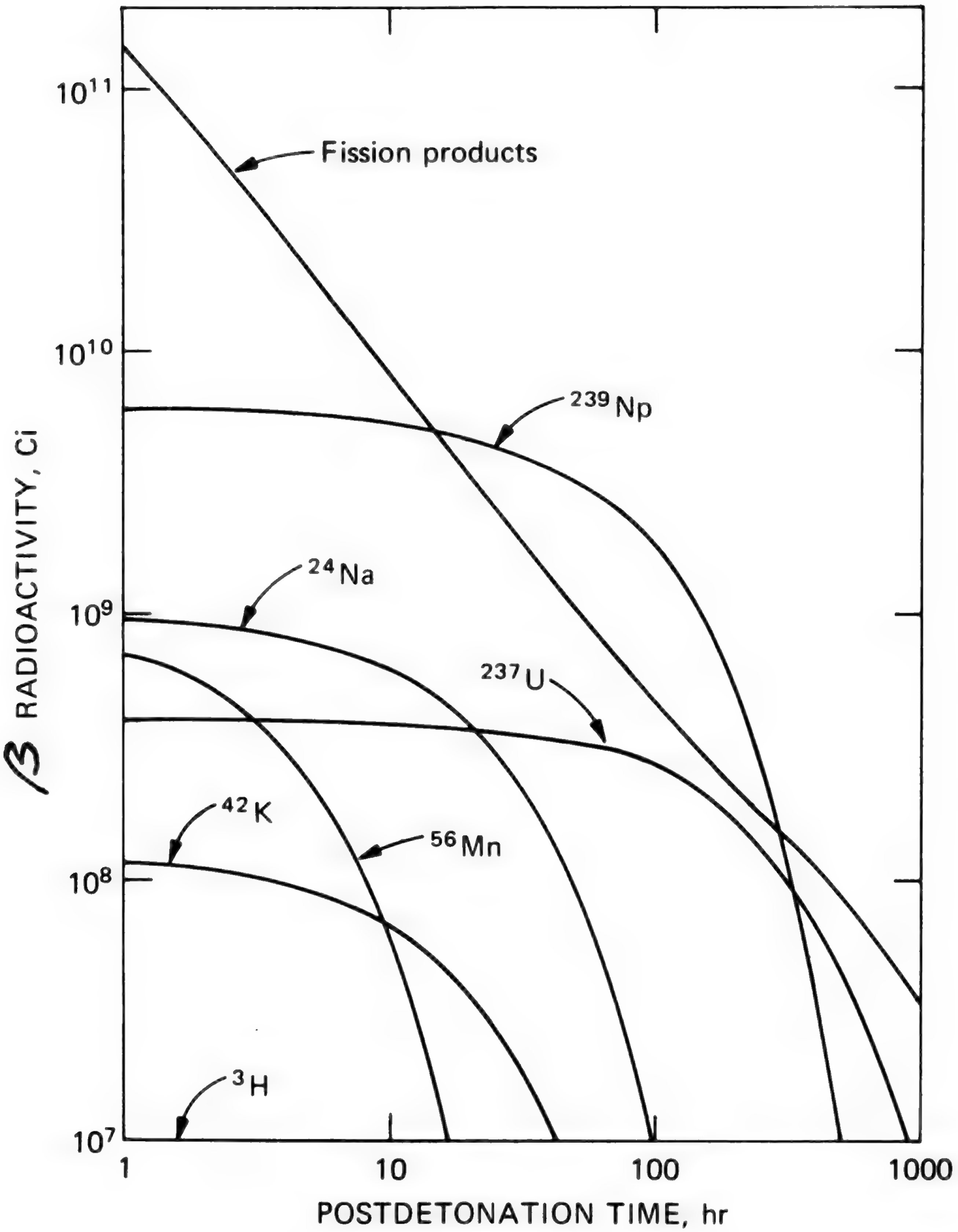


Fig. 1 Percent of area of the continental United States enclosed within selected I_s contours as a function of attack weight (50% fission weapons).



Radioactivity from 1-Mt explosive with a fission-to-fusion ratio of 1.0.

Local Fallout from Nuclear Test Detonations (U), DASA 1251-series (5 volumes with 9 separately-bound parts), by U.S. Army Nuclear Defense Laboratory for the Defense Atomic Support Agency:

Volume I, Indexed Bibliography of United States and British Documents on Characteristics of Local Fallout (U), DASA 1251-1 (AD 329971), 237 pp., 27 June 1961. (C)

Volume II, Compilation of Fallout Patterns and Related Test Data (U):

Part 1 - Trinity Through Redwing (U), DNA 1251-2-1 (AD 349123), 468 pp., August 1963. (SRD)

Part 2 - Plumbbob Through Hardtack (U), DASA 1251-2-2 (AD 329124), 456 pp., August 1963. (SRD)

Part 3 - Nougat Through Niblic (U), DASA 1251-2-3 (AD 371725), 226 pp., March 1966. (SRD)

Supplement, Foreign Nuclear Tests (U), DASA 1251 (AD 358417L), 77 pp., October 1964. (SRD)

Volume III, Annotated Compendium of Data on Physical and Chemical Properties of Fallout (U), DASA 1251-3 (AD 381963L), 770 pp., November 1966. (SRD)

Volume IV, Annotated Compendium of Data on Radiochemical and Radiation Characteristics of Fallout (U):

Part 1 - Specific Activity, Activity-Size Distribution, Decay (U), DASA 1251-4-1 (AD 500919L), 643 pp., September 1968. (SRD)

Part 2 - Radiochemical Composition, Induced Activity, Gamma Spectra (U), DASA 1251-4-2 (AD 523385), 570 pp., 31 May 1972. (SRD)

Volume V, Transport and Distribution of Local (Early) Fallout from Nuclear Weapon Tests (U), DASA 1251-5 (AD 362012), 580 pp., May 1965. (SRD)

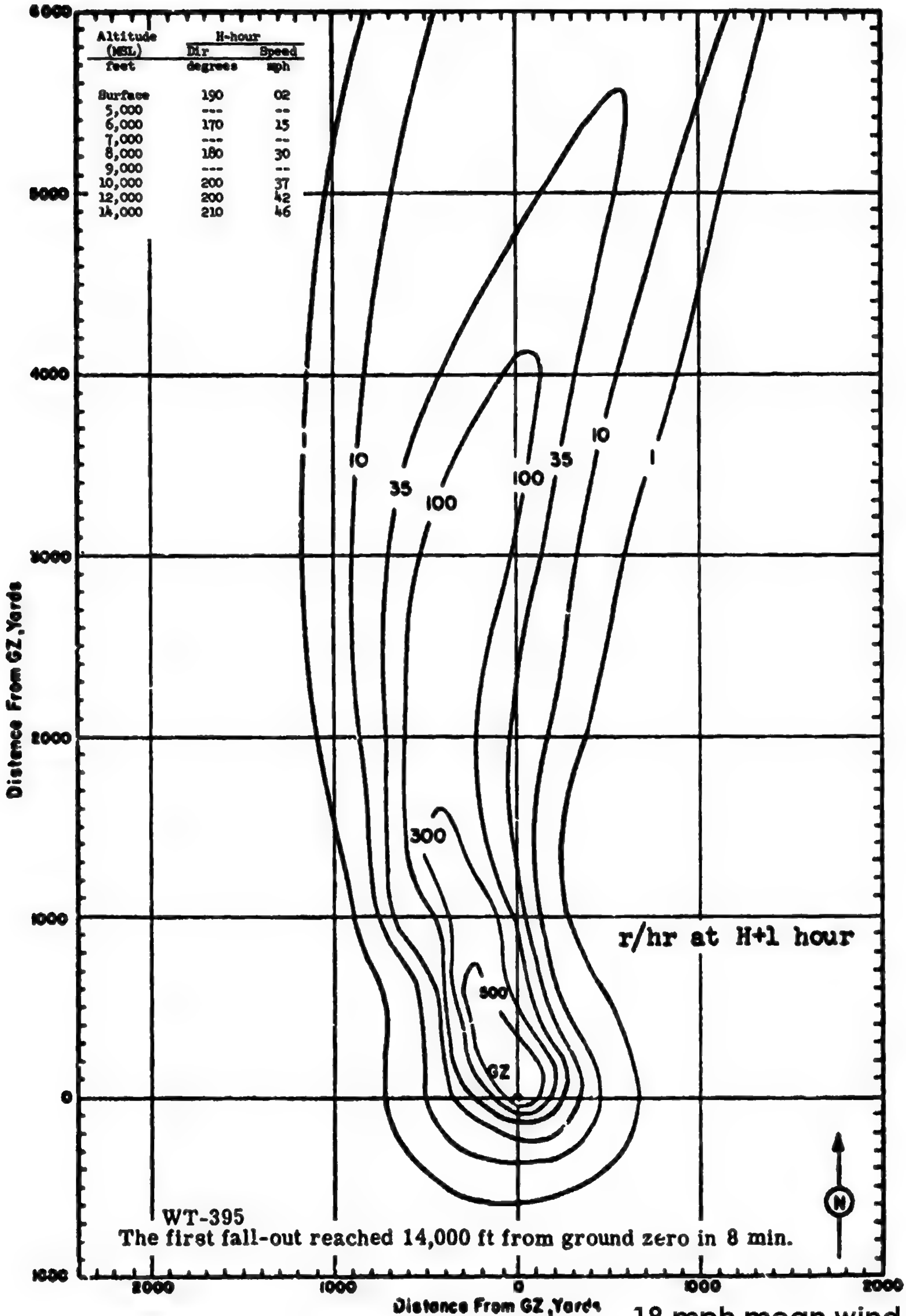
1.2 kt JANGLE - Sugar Surface burst 19 Nov 1951

CLOUD TOP HEIGHT: 15,000 ft MSL

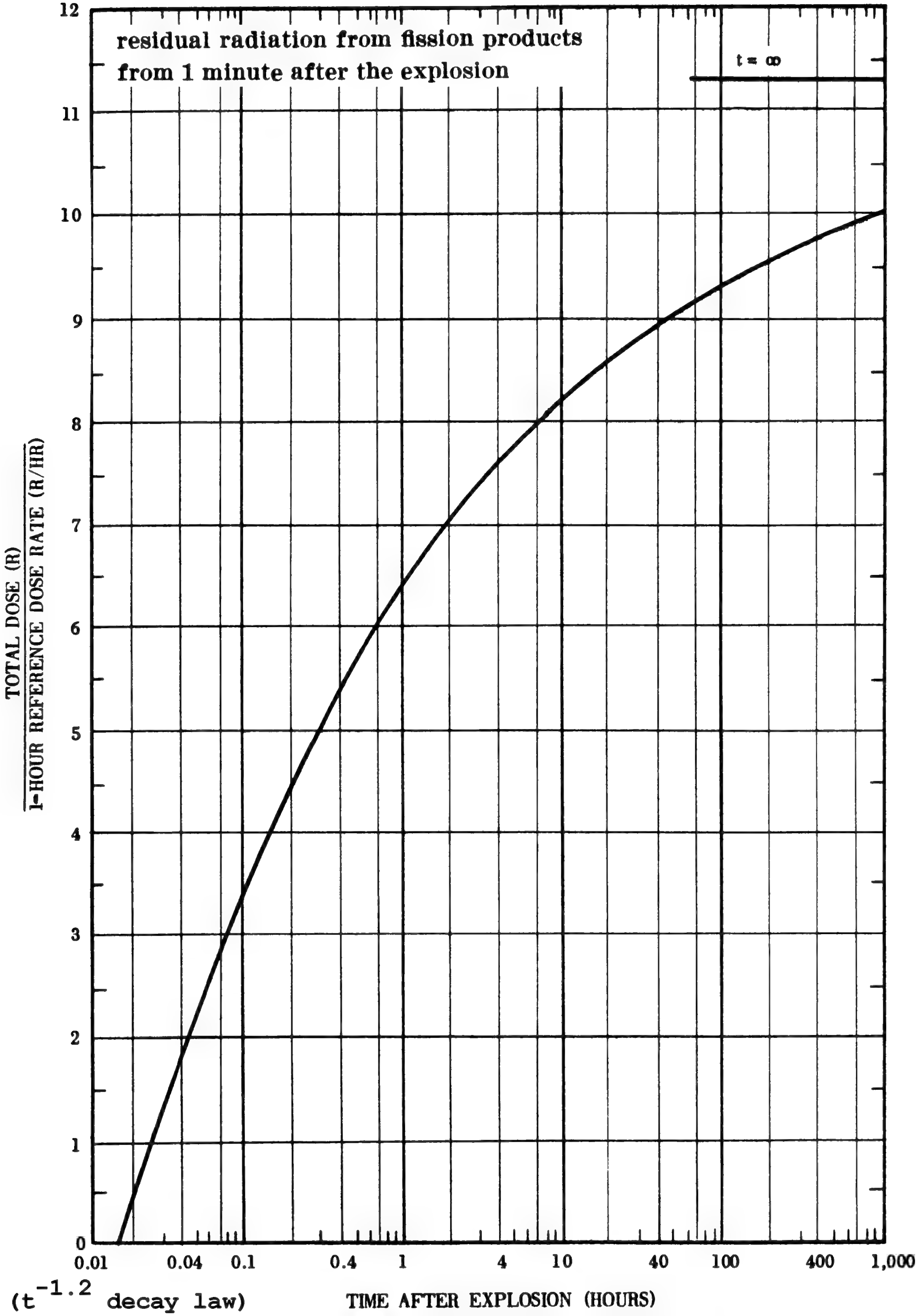
CRATER DATA: Diameter: 90 ft — Depth: 21 ft — maximum dose rate: 7500 r/hr at H+1 hour at crater lip

Maximum dose rate		Maximum contour distance from GZ (ft)			Contour area (sq mi)		
Value (r/hr)	Distance from GZ (ft)	500 r/hr	300 r/hr	100 r/hr	500 r/hr	300 r/hr	100 r/hr
540	900	2200	4900	12,500	0.05	0.15	0.55

Laurino, R. K., and I. G. Poppoff, 1953: *Contamination patterns at Operation JANGLE.* U. S. Nav. Rad. Def. Lab. Rep. USNRDL-399, 28 pp.

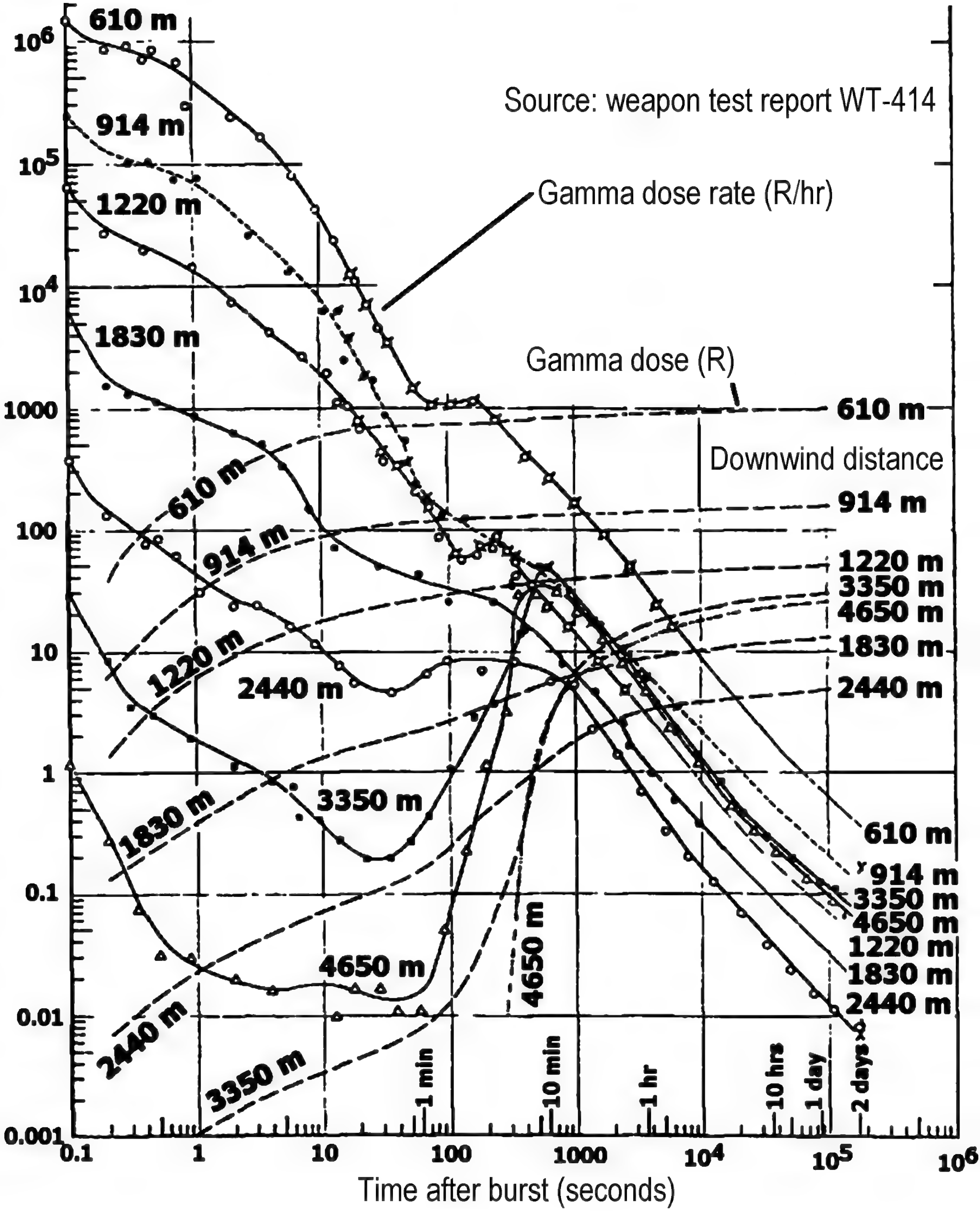


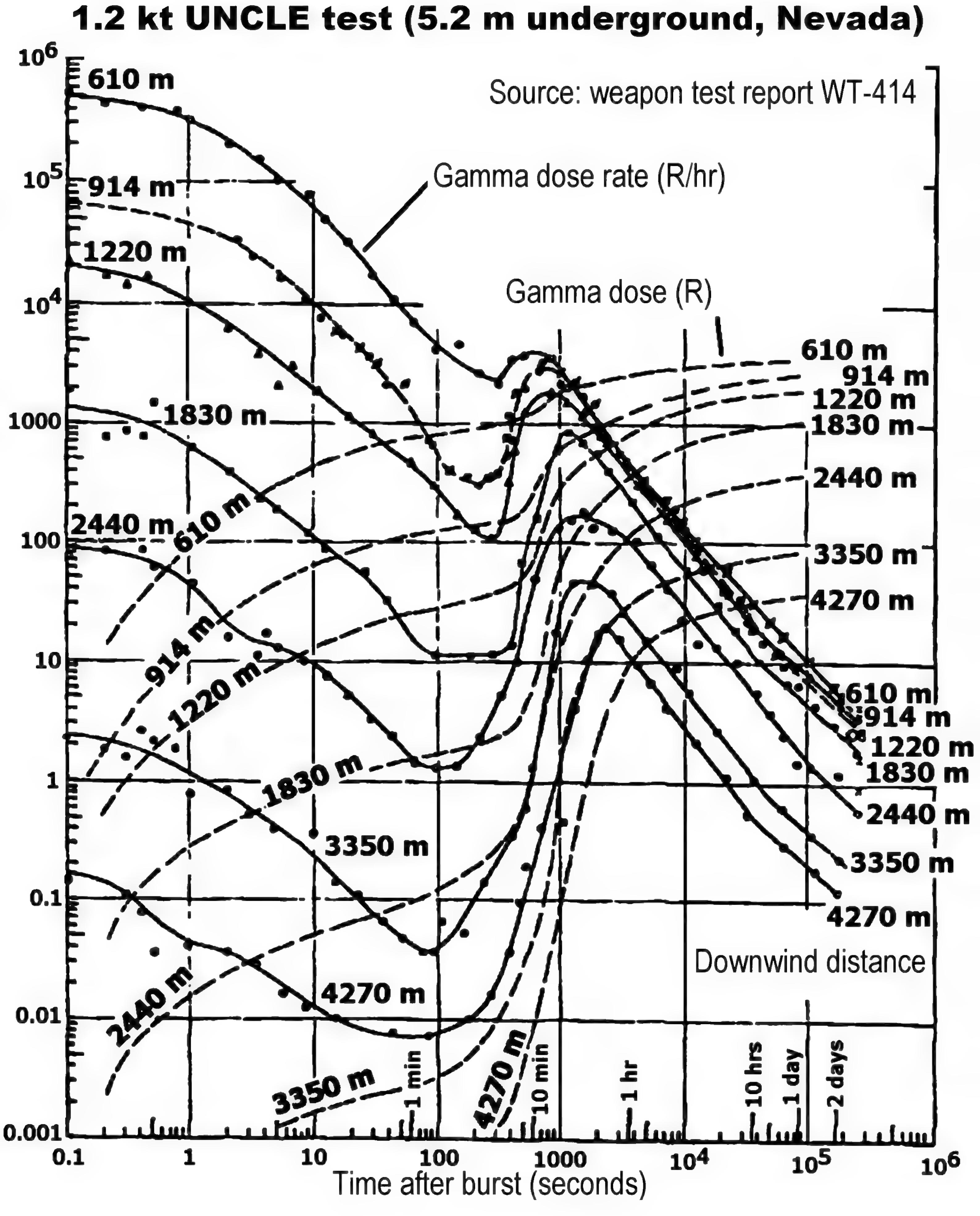
18 mph mean wind speed



($t^{-1.2}$ decay law)

1.2 kt SUGAR test (Nevada surface burst)





1.2 kt UNCLE test (5.2 m underground, Nevada)
Source: weapon test report WT-414
Gamma dose rate (R/hr)
Gamma dose (R)
Downwind distance
610 m
914 m
1220 m
1830 m
2440 m
3350 m
4270 m
1 min
10 min
1 hr
10 hrs
1 day
2 days
Time after burst (seconds)

Robbins, Charles; et al. "Airborne Particle Studies, JANGLE Project 2.5a-1." (In: Operation JANGLE, Particle Studies, WT-371-EX, 417 pages.) Army Chemical Center. Washington, D. C.: AFSWP. WT-394-EX. October 1979. 198 Pages. AD/A995 072.

OPERATION JANGLE

Project 2.5a-1

AIRBORNE PARTICLE STUDIES

by

Lt. Col. Charles Robbins
Chemical Corps

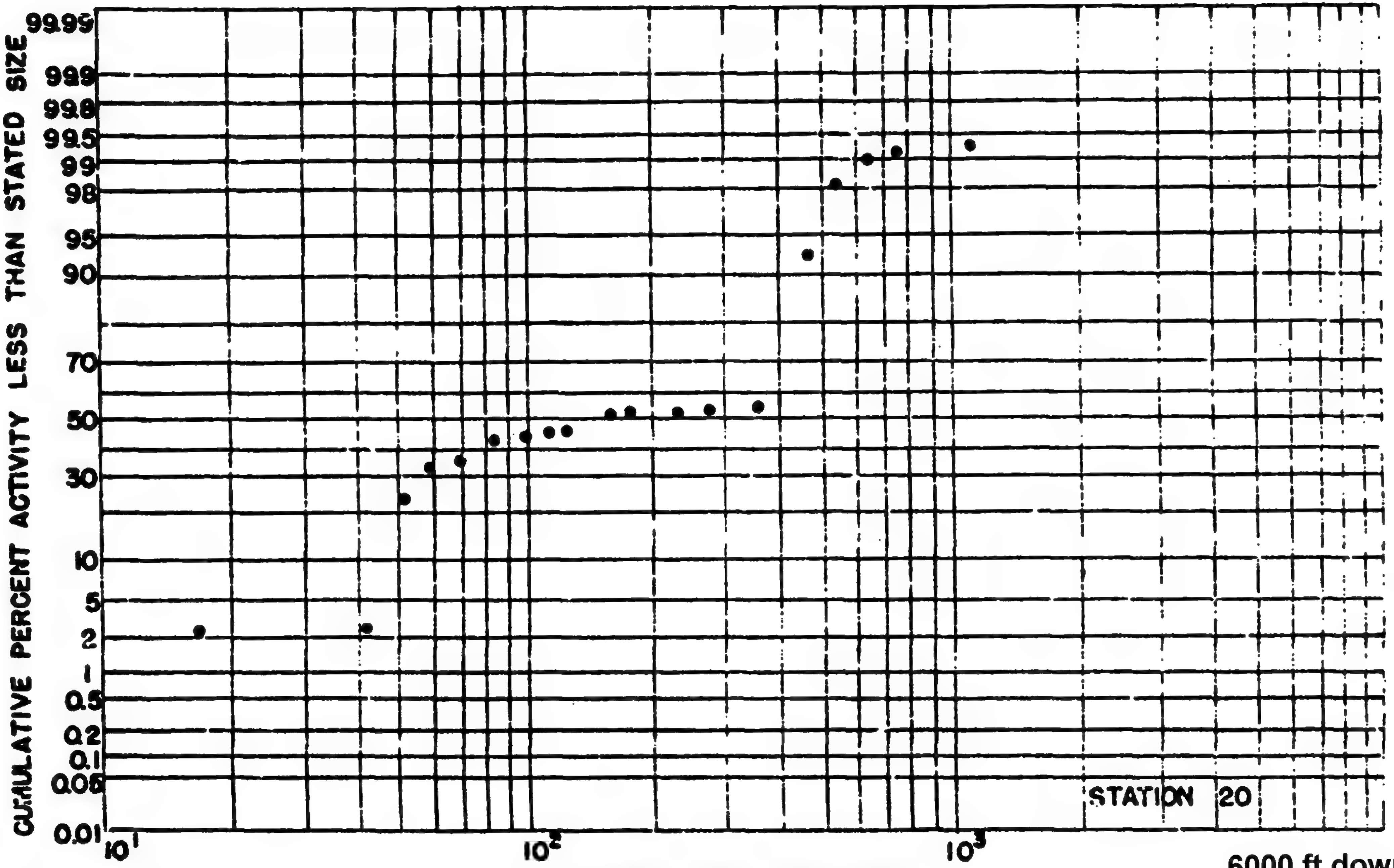
Major Hugh R. Lehman
U. S. Air Force

David R. Powers
Chemical Corps

James D. Wilcox
Chemical Corps

July 1952

CHEMICAL AND RADIOLOGICAL LABORATORIES
Army Chemical Center, Maryland



6000 ft downwind
1.8 km downwind

Fig. 2.24 Fall-out Activity as a Function of Particle Size, Station 20, Surface Shot.

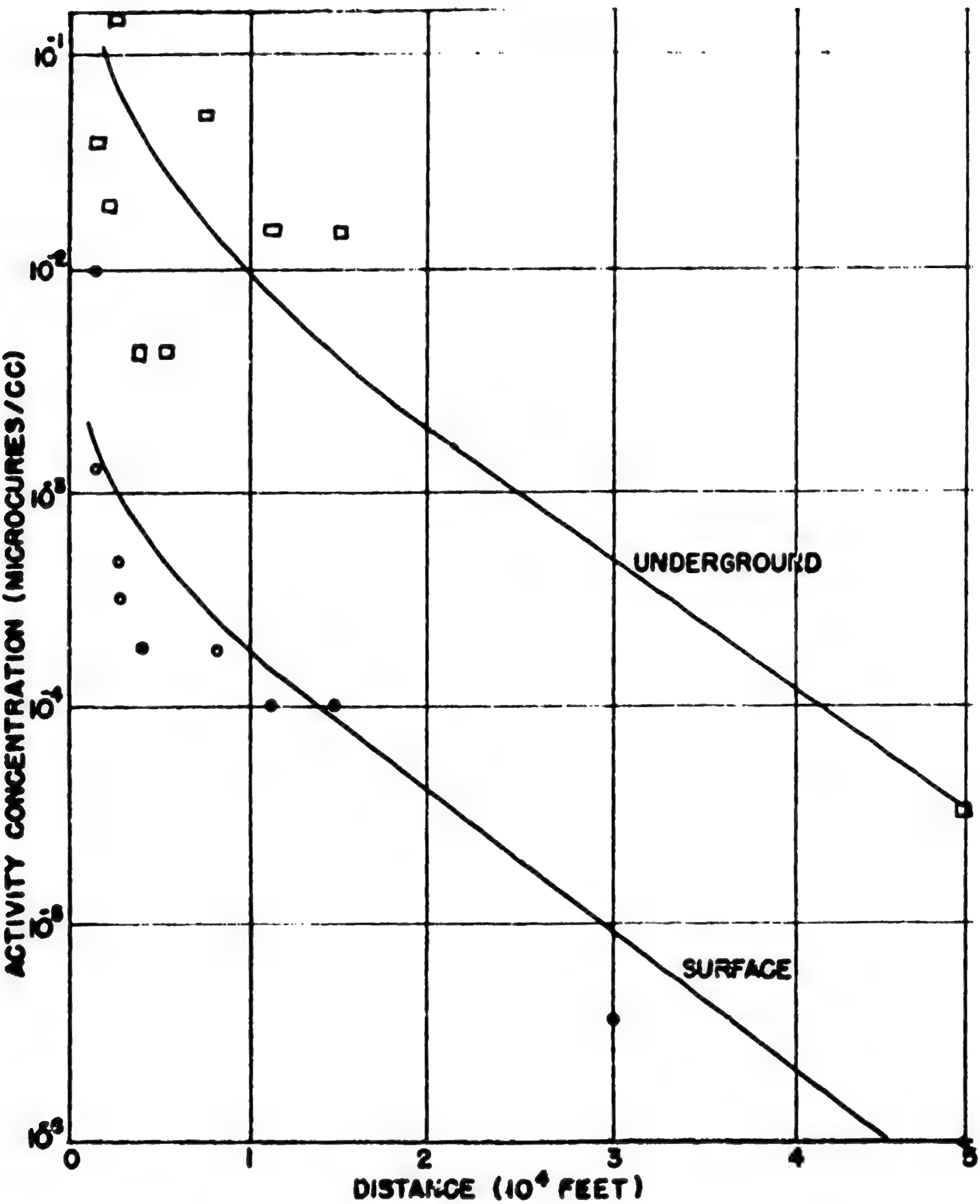


Figure 5.1 Concentration of Activity in the Cloud as a Function of Distance on the Down-wind Leg. Filter Sampler Data. Activity was corrected to time at which cloud passed each station.

5.5 STUDY OF FRACTIONATION

5.5.1 Radiochemistry

The data concerning the nuclide activity per unit mass of active material as a function of particle size, which is contained in Table 4.15, provided a method of investigating the mechanism whereby particles acquire activity. The data for Sr^{89} and ZR^{95} have been plotted in Figs. 5.4 and 5.5. Referring to Fig. 5.4, it appears that a straight line with a slope of -1 may be fitted to the data, whereas this is not possible with the data in Fig. 5.5. Allowing for some over-simplification, it appears that the Sr^{89} activity is a function of particle surface, whereas that for Zr^{95} tends to be more of a volume function. Ba^{140} gives a plot similar to the Sr^{89} plot, while Ce^{144} is similar to Zr^{95}. Further study is being made of these data, particularly with respect to the question of whether the activity of Zr^{95} and Ce^{144} is concentrated in a shell rather than a volume. Examination of the decay chains of these four nuclides provides a plausible reason why there should be a difference in the mechanism for acquiring radioactivity. The decay chains are as follows[4]:

$Kr^{89} \xrightarrow{2.6m} Rb^{89} \xrightarrow{15.4m} Sr^{89}$

$Kr^{95} \xrightarrow{short} Rb^{95} \xrightarrow{short} Sr^{95} \xrightarrow{short} Y^{95} \xrightarrow{10.5m} Zr^{95}$

$Xe \xrightarrow{16s} Cs \xrightarrow{66s} Ba^{140}$

$Xe^{144} \xrightarrow{1s} Cs^{144} \xrightarrow{short} Ba^{144} \xrightarrow{short} La^{144} \xrightarrow{short} Ce^{144}$

It may be seen that Ba^{140} and Sr^{89} both have gaseous precursors that have half-lives long in comparison with the lifetime of the fireball. Since gases such as krypton and xenon are not significantly subject to adsorption above liquid air temperatures, it is logical to suppose that while the Zr^{95} and Ce^{144} chains passed the rare gas stage early enough to be adsorbed during the particle growth process, no appreciable amount of Kr^{89} and Xe^{140} decayed before the particles had ceased to grow. Hence the Sr^{89} and Ba^{140} activities were confined to the outermost surfaces of the particles.

---

[4] C. D. Coryell & N. Sugarman, op cit, pp. 1996-2001.

8.9 INHALATION STUDIES

Dogs and sheep were exposed on the ground surface and in foxholes at distances of 2500 to 8000 feet in the predicted downwind direction from each shot. The purpose of the exposure was to allow the assessment of hazards due to inhalation of radioactive dusts associated with these detonations and to compare internal and external radiation dosages.

Total body activity for animals exposed in the underground test ranged from 2 to 31 microcuries corrected to time of sacrifice. For lung tissue, integrated dosage due to beta emission ranged between 0.2 and 9.0 rep. Radioautographs of lung tissues indicated the presence of a few alpha emitting particles. Bone analyses indicated some uptake of Ba^{140} and Sr^{90}.

The amounts of activity taken up by the combined action of inhalation and ingestion are not considered to be physiologically significant even for animals receiving cumulative external gamma radiation dosages up to several thousand roentgens.

9.8 CLOTHING DECONTAMINATION AND EVALUATION OF LAUNDRY METHODS

Standard and special U. S. Army Quartermaster Corps laundering methods and standard laundry equipment were evaluated for field decontamination of clothing and selected fabrics. No clothing worn by personnel became contaminated to a significant degree during this operation. Therefore, this project was carried out with clothing deliberately contaminated with radioactive material from the fall-out area.

The project evaluated the standard and several special laundering formulae, various types of clothing materials, and monitoring instruments (Project 6.7). The significant result of this project is the indication that clothing contamination resulting from work in areas contaminated by atomic bomb detonations will not produce even minor injury to personnel. This conclusion is based on consideration of the data on saturation values of deliberate clothing contamination reduced to one hour after detonation. The resultant exposure to personnel would be less than that required to produce even slight skin irritation (comparable to mild sunburn). Other conditions, such as muddy terrain and much higher specific activity, could increase the amount of contamination received by clothing, but an increase in level of several orders of magnitude would be required to produce injury. In these cases it is certain that routine standards of cleanliness would effectively prevent injury from this cause.

WT-393
Copy

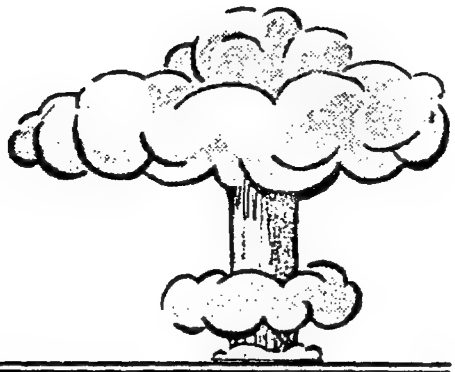
Operation

JANGLE

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 2.3-2

FOXHOLE SHIELDING OF GAMMA RADIATION



ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON D.C.

PROJECT 2.3-2

TABLE 3.1

Distribution of Gamma Radiation in Foxholes (Surface Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface		800 r				
	Surface		700				
	16" Below Surface	230	205	415			
	32" Below Surface	24	58	136			
	48" Below Surface	12.8	22	62			
2500	36" Above Surface		230 r				
	Surface		220				
	16" Below Surface	35	60	85			
	32" Below Surface	7	15	26			
	48" Below Surface	4	8.5	13.3			
3000	36" Above Surface		110 r				73 r
	Surface		90			55	
	16" Below Surface	23	36	55	6.8	6.6	10
	32" Below Surface	7.6	12.4	19.4	2.5	2.4	0.5
	48" Below Surface	2.5	4.8	6.7	1.6	1	0
3500	36" Above Surface		41 r				
	Surface		—				
	16" Below Surface	3	—	9.7			
	32" Below Surface	1.6	2.8	3.4			
	48" Below Surface	.54	.99	1.9			
4000	36" Above Surface		17 r				17 r
	Surface		9.6			—	
	16" Below Surface	1.6	3	5.6	—	0.35	—
	32" Below Surface	0.6	1.12	1.62	—	—	0.17
	48" Below Surface	—	0.54	0.57	0.39	—	—
4500	36" Above Surface		9.8 r				
	Surface		4.6				
	16" Below Surface	1	1.8	3.5			
	32" Below Surface	0.5	0.7	1.04			
	48" Below Surface	0.21	0.4	0.57			
5000	36" Above Surface		4.8 r				
	Surface		2.7				
	16" Below Surface	0.6	0.99	2.95			
	32" Below Surface	0.3	0.5	0.75			
	48" Below Surface	0.17	0.2	0.38			

PROJECT 2.3-2

TABLE 3.2

Distribution of Gamma Radiation in Foxholes (Underground Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface		3850 r				
	Surface		2300				
	16" Below Surface	1150	--	800			
	32" Below Surface	700	1000	555			
	48" Below Surface	200	200	200			
2500	36" Above Surface		1000 -- 550 r				
	Surface		78				
	16" Below Surface	78	98	115			
	32" Below Surface	43	56	50			
	48" Below Surface	73.4	94	96			
3000	36" Above Surface		175 r				155 r
	Surface		103			75	
	16" Below Surface	30	42	37	20	--	7
	32" Below Surface	22	23	20	15	11	3
	48" Below Surface	43.5	45	54	41	38	3
3500	36" Above Surface		--				
	Surface		48				
	16" Below Surface	12	17	15			
	32" Below Surface	9	10	9			
	48" Below Surface	15	15	22			
4000	36" Above Surface		32 r				28 r
	Surface		22			14	
	16" Below Surface	6	7	15	7	4	2
	32" Below Surface	5	3.4	7.2	3.7	2.8	0
	48" Below Surface	6	8.4	8.6	5	9.8	1.1
4500	36" Above Surface		22 r				
	Surface		10				
	16" Below Surface	4	5	5			
	32" Below Surface	5.8	2.8	2.8			
	48" Below Surface	--	7.7	8.9			
5000	36" Above Surface		73 r				
	Surface		23				
	16" Below Surface	15	15	67			
	32" Below Surface	21.5	22.6	15			
	48" Below Surface	--	21	19			

CHAPTER 5

CONCLUSIONS

5.1 FOXHOLE SHIELDING OF GAMMA RADIATION

5.1.1 Surface Detonation

Standard foxholes provide excellent protection to personnel from the gamma radiation emitted during the detonation of an atomic weapon on the surface of the ground. The results from the comparatively small sized weapon employed in Operation JANGLE show that 2000 feet from the burst, the location of the closest foxhole doses of about 60r were measured at the bottom of a foxhole, less than 10 per cent of the dose measured 3 feet above the surface of the ground. Due to the location of the foxhole in the crosswind direction, the dose at the bottom was caused primarily by scattered prompt radiation plus a small contribution from the residual activity of the fission products on the surface of the ground. In the downwind direction there would be a contribution from matter that falls out from the cloud into the foxhole in addition to the above mentioned. This fall-out will depend on the wind velocity for a given sized weapon, and although it is expected to increase the dose in the foxholes, especially in those located close to the detonation, it is relatively unimportant in comparison to the prompt and residual activity since it can be easily shoveled out of the foxhole in a short time.

5.1.2 Underground Detonation

With the possible exception of those located in the area close to the point of detonation where extensive fall-out occurs, foxholes also provide effective shielding in the case of an underground detonation. Even within this area of extensive fall-out, which at Operation JANGLE extended approximately 2000 feet, the high doses recorded in the foxholes could be greatly reduced by digging out the radioactive matter that fell into the hole. It is highly probable that one-half the doses recorded in the foxholes located within 2500 feet of the detonation at Operation JANGLE were directly attributable to this type of fall-out and most likely a higher percentage at distances greater than 2500 feet.

TOP SECRET UK National Archives PREM 11/560, 12 July 1951

PRIME MINISTER

Clandestine Use of Atomic Weapons

The Chiefs of Staff have been considering the possibility that the enemy might open the next war with an atomic attack on London on the model of the Japanese attack on Pearl Harbour - without warning and before any formal declaration of hostilities. The most effective method of making such an attack would be to drop an atomic bomb from a military aircraft. If the control and reporting system were fully manned and alert in a period of tension, there would be some chance that hostile aircraft approaching this country could be intercepted and driven off. At any rate, there are no special measures, outside the normal measures of air defence, which we could take in peace-time to guard against this type of attack.

2. It is, however, possible that the enemy might use other means of surprise attack with atomic weapons. A clandestine attack could be made in either of the following ways:-

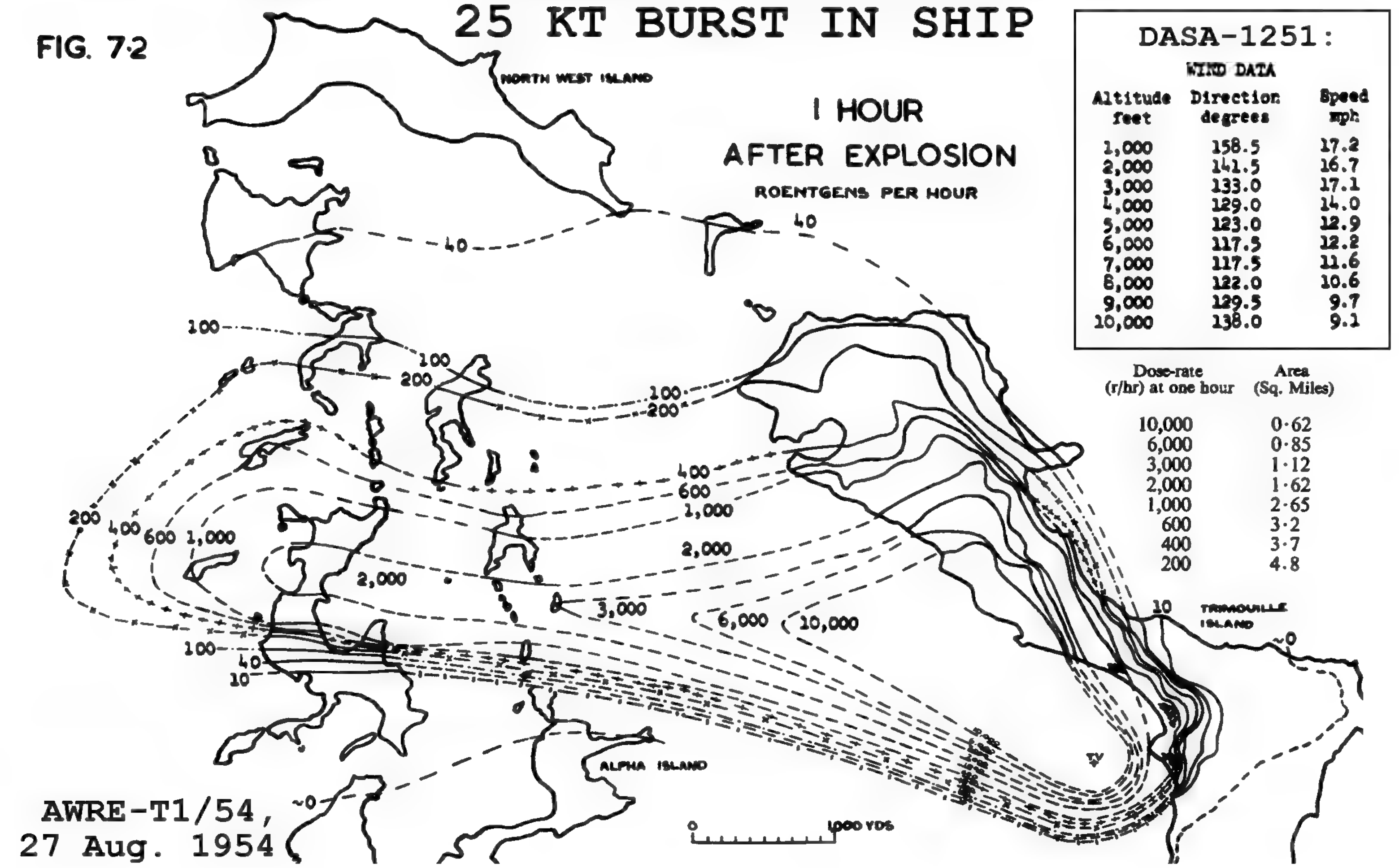
(i) A complete atomic bomb could be concealed in the hold of a merchant ship coming from the Soviet Union or a satellite country to a port in the United Kingdom:

(ii) An atomic bomb might be broken down into a number of parts and introduced into this country in about fifty small packages of moderate weight. None of these packages could be detected by instruments as containing anything dangerous or explosive, and even visual inspection of the contents of the packages would not make identification certain. These packages could be introduced either as ordinary merchandise from Soviet ships, or possibly as diplomatic freight. The bomb could subsequently be assembled in any premises with the sort of equipment usual in a small garage, provided that a small team of skilled fitters was available to do the job.

OPERATION HURRICANE—THE DOSE-RATE CONTOURS OF THE RESIDUAL RADIOACTIVE CONTAMINATION

25 KT BURST IN SHIP

FIG. 7·2



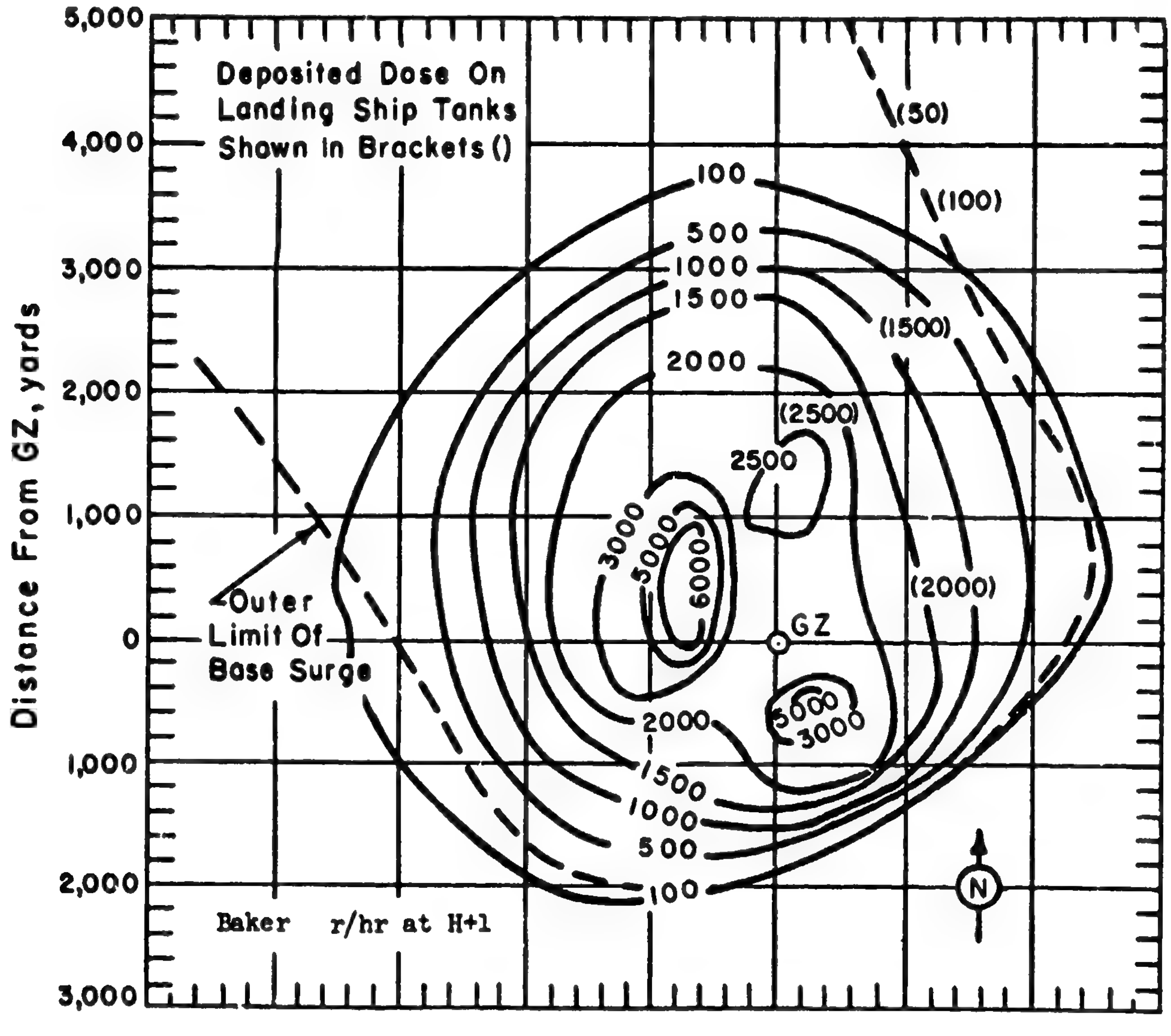
DASA-1251:

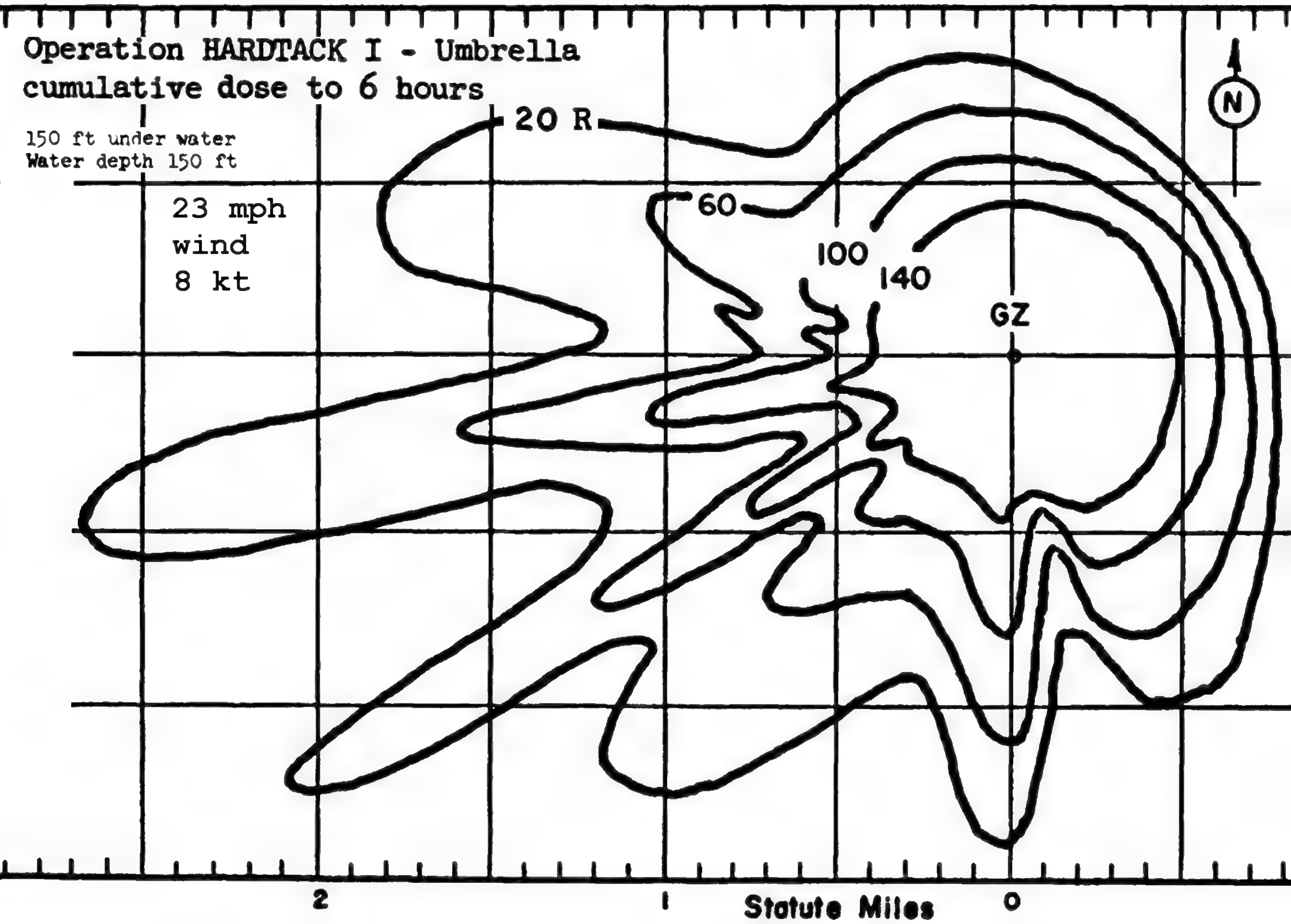
WIND DATA

Altitude feet	Direction degrees	Speed mph
1,000	158.5	17.2
2,000	141.5	16.7
3,000	133.0	17.1
4,000	129.0	14.0
5,000	123.0	12.9
6,000	117.5	12.2
7,000	117.5	11.6
8,000	122.0	10.6
9,000	129.5	9.7
10,000	138.0	9.1

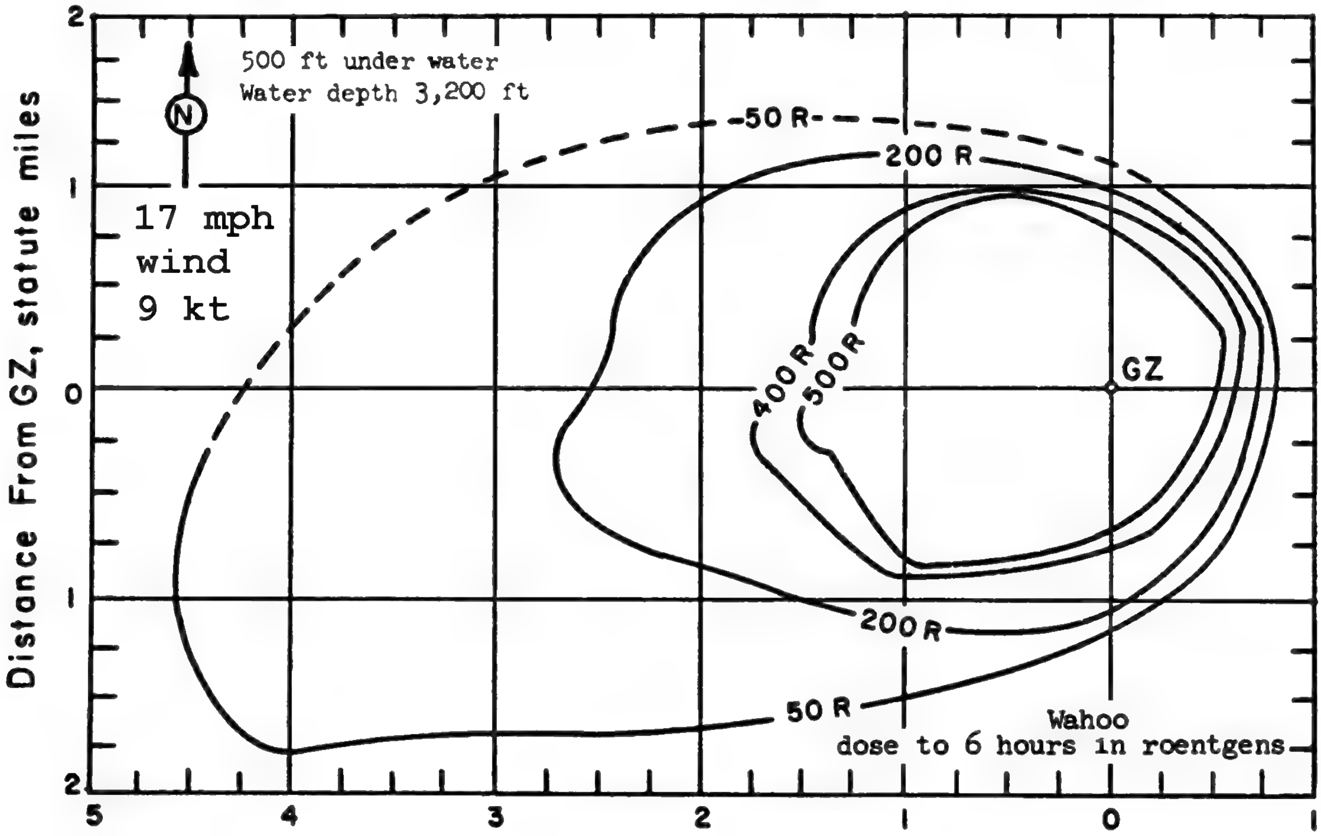
Dose-rate (r/hr) at one hour	Area (Sq. Miles)
10,000	0·62
6,000	0·85
3,000	1·12
2,000	1·62
1,000	2·65
600	3·2
400	3·7
200	4·8

AWRE-T1/54, 27 Aug. 1954





Operation HARDTACK I - Umbrella
cumulative dose to 6 hours
150 ft under water
Water depth 150 ft
23 mph
wind
8 kt
N
20 R
60
100
140
GZ
2
1
Statute Miles
0



500 ft under water
Water depth 3,200 ft
N
17 mph
wind
9 kt
50 R
200 R
400 R
500 R
GZ
200 R
50 R
Wahoo
dose to 6 hours in roentgens
Distance From GZ, statute miles
2
1
0
1
2
5
4
3
2
1
0
1

WT-1316 (EX)
EXTRACTED VERSION

OPERATION REDWING

Project 2.62a
Fallout Studies by Oceanographic Methods

Pacific Proving Grounds

May - July, 1956

Defense Atomic Support Agency

Sandia Base, Albuquerque, New Mexico

February 6, 1961

NOTICE

This is an extract of **WT-1316, Operation REDWING, Project 2.62a**, which remains classified **Secret/ Restricted Data** as of this date.

Extract version prepared for:

Director
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

1 February 1980

TABLE 2.11

	Navajo	Tewa
Total Yield, Mt	4.50	5.01
Fission proportion	5%	87%
H + 1 Hour Dose Rate (r/hr)	Area (mi^2) Within Contour	
1,000	25	450
500	55	1,050
300	80	1,550
100	310	3,500
Two-day Dose, R	Area (mi^2) Within Contour	
1,000	20	520
500	30	1,050
300	45	1,500
100	350	3,000

CLEAN BOMB: 3.53 MT (15% FISSION) ZUNI

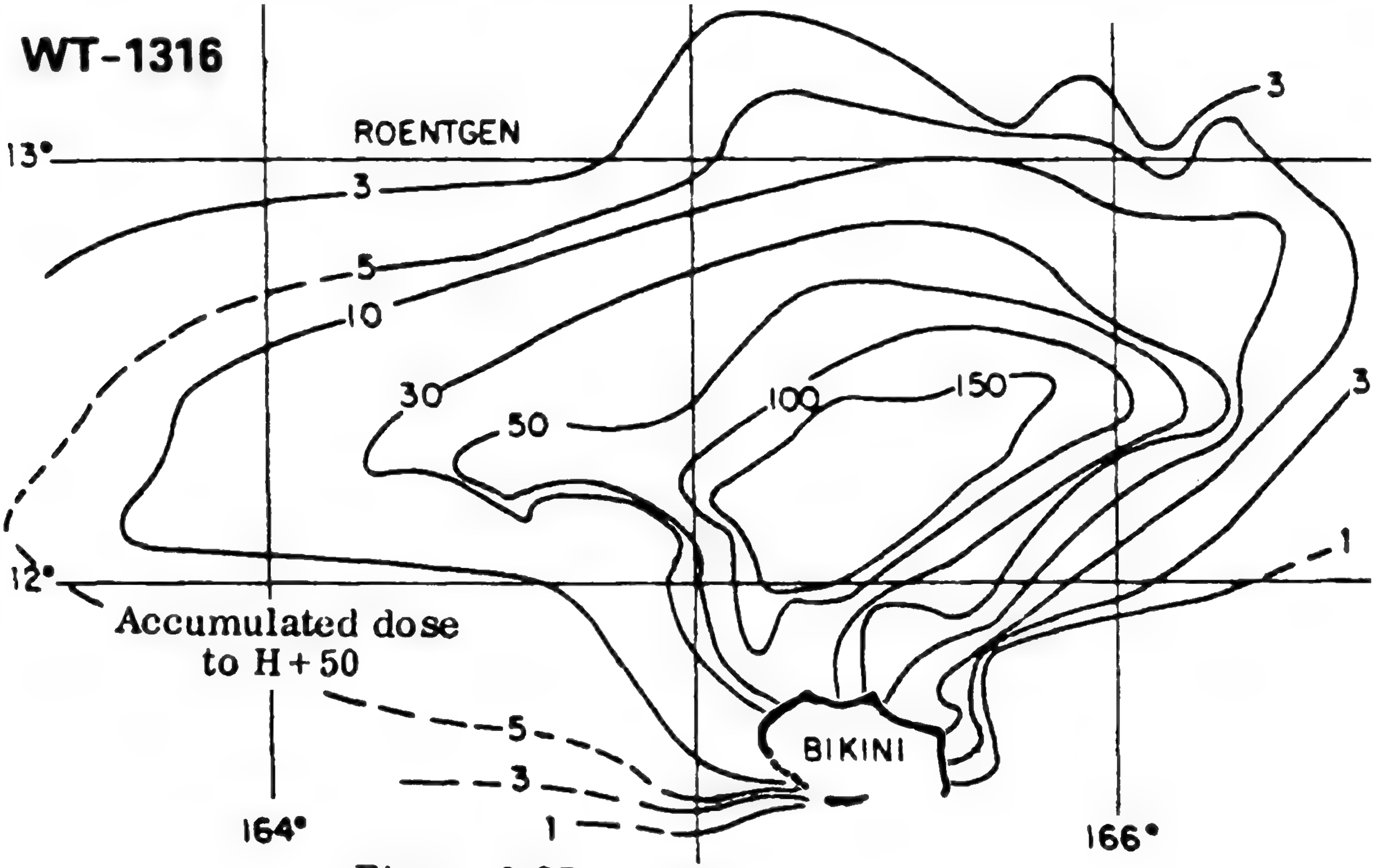


Figure 2.37

DIRTY BOMB: 5.01 MT (87% FISSION) TEWA

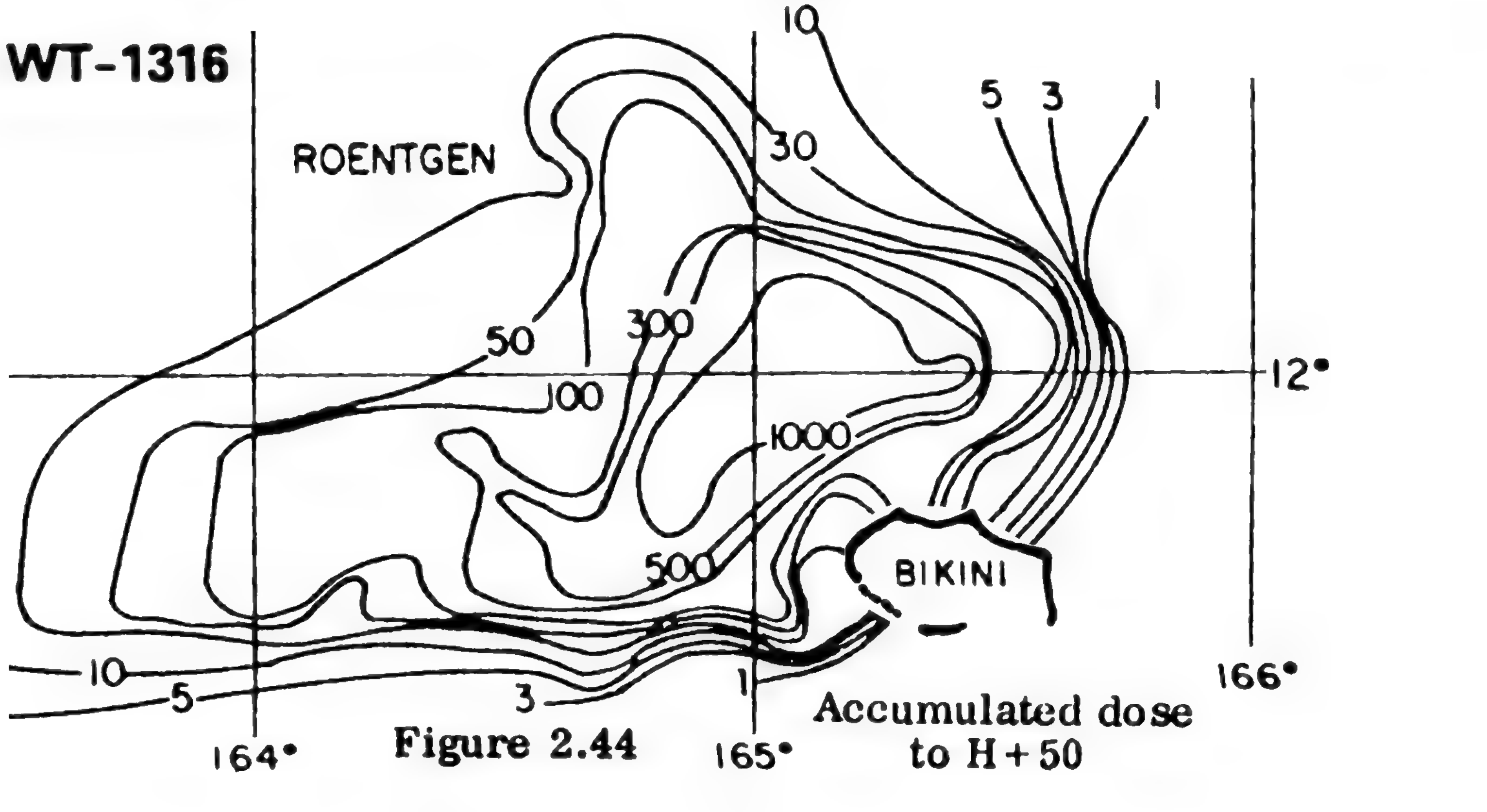
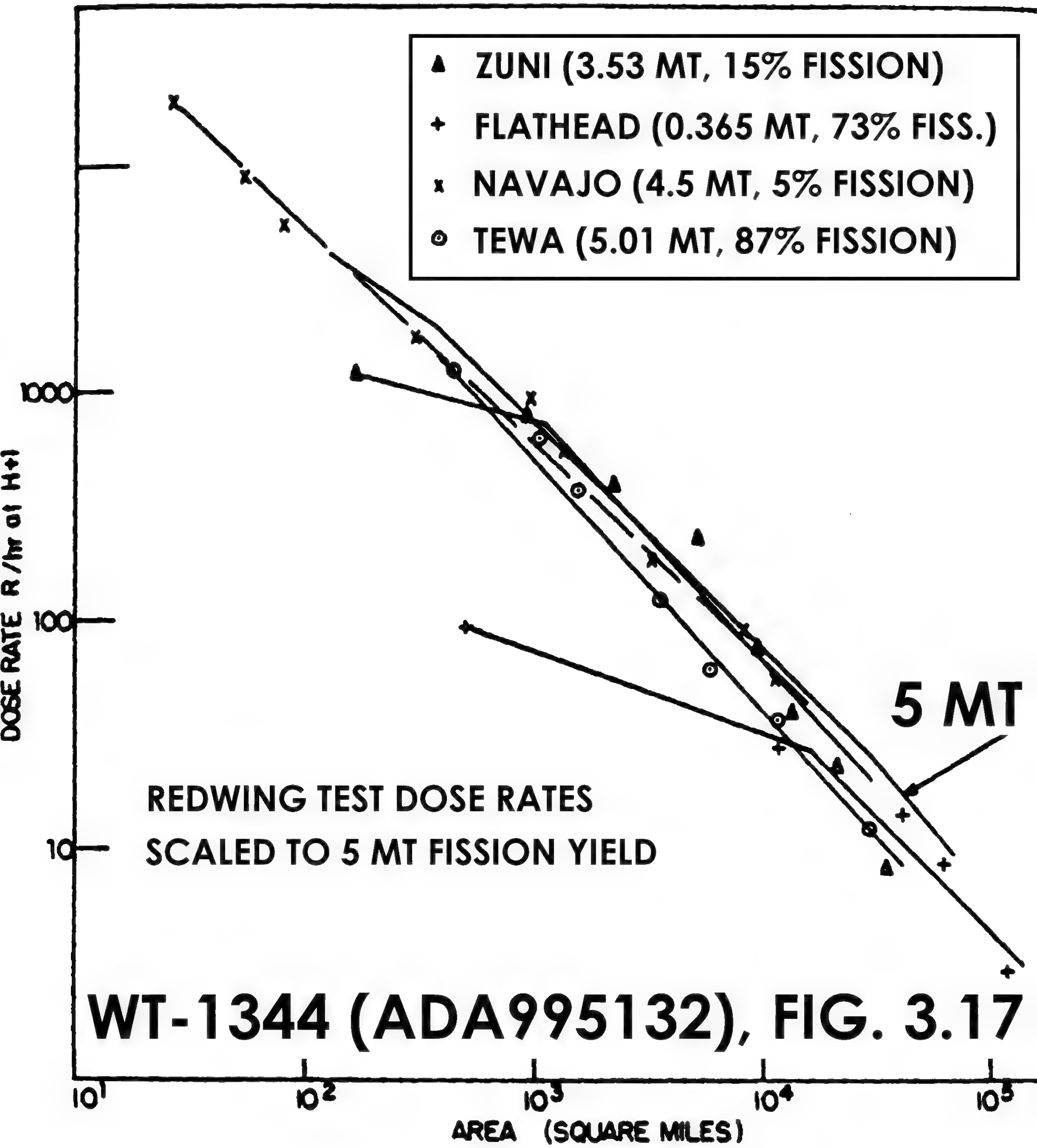
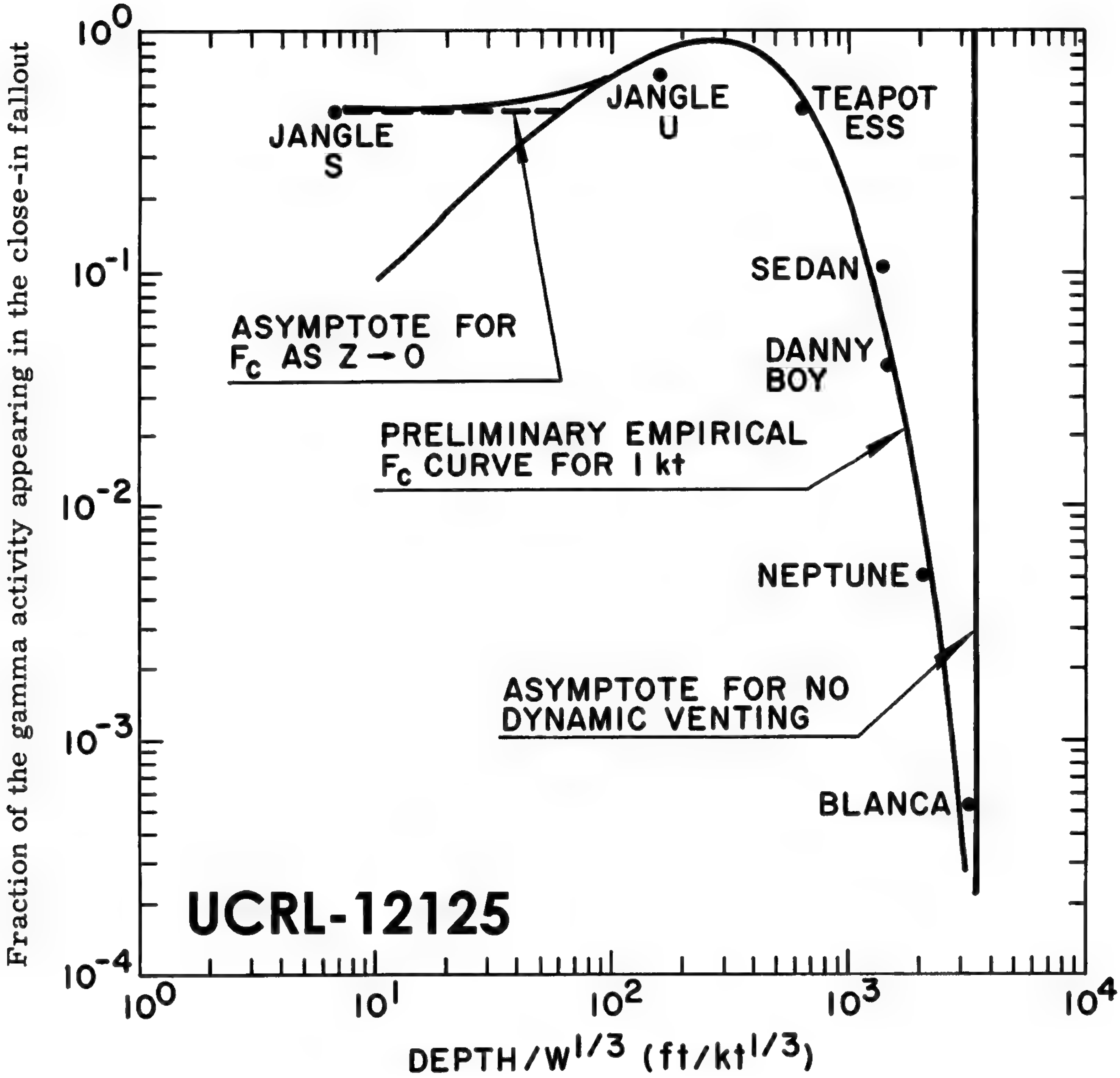


Figure 2.44

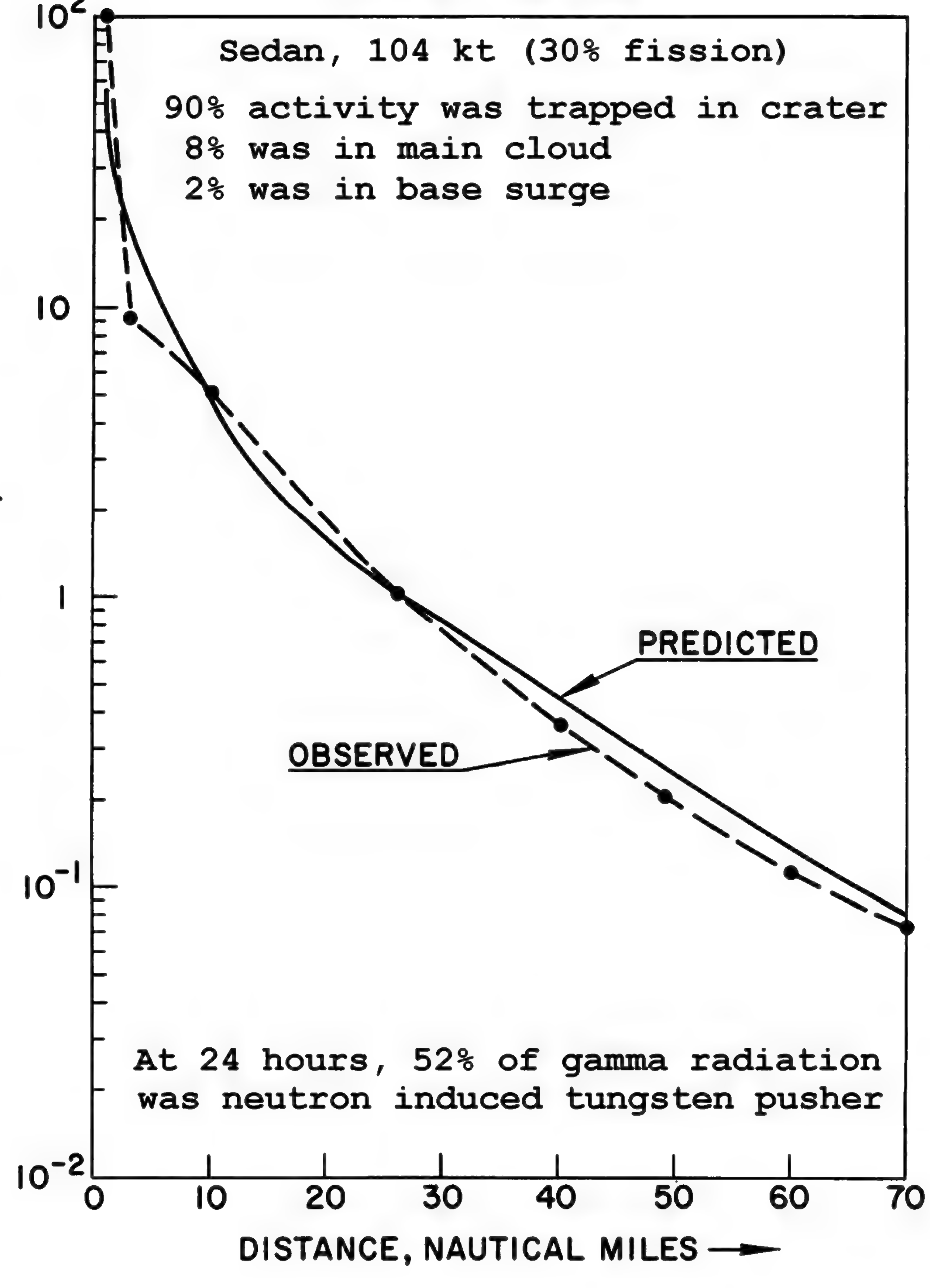


WT-1344 (ADA995132), FIG. 3.17

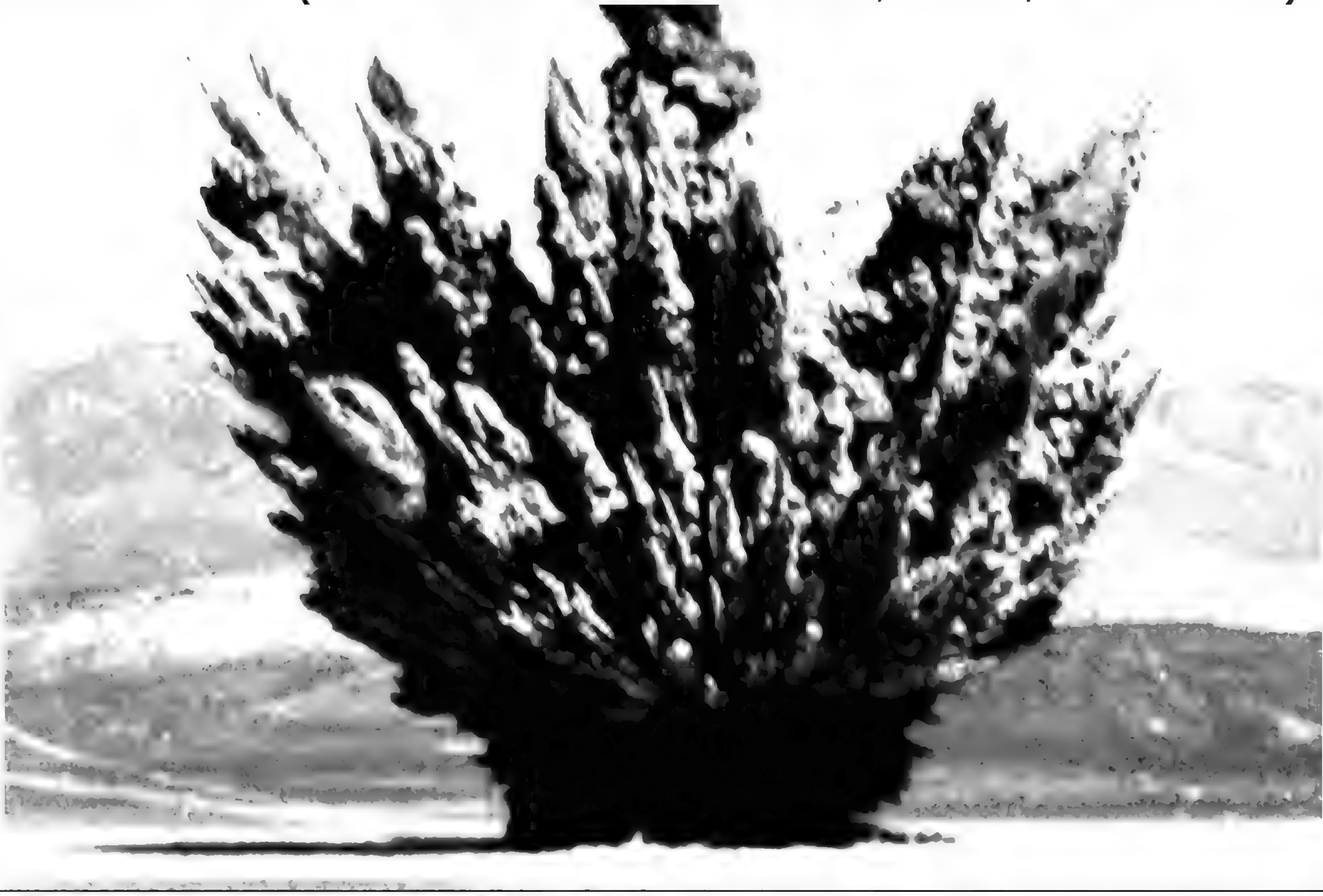


UCRL-12125

Event	W, kt	z, ft	F	Medium
Sedan	100	635	0.10	Alluvium
Teapot ESS	1.2	67	0.46	Alluvium
Jangle U	1.2	17	0.64	Alluvium
Neptune	0.115	100	0.005	Tuff
Jangle S	1.2	0	0.50	Alluvium
Danny Boy	0.43	109	0.04	Basalt
Blanca	19	835	0.0005	Tuff


Sedan, 104 kt (30% fission)
90% activity was trapped in crater
8% was in main cloud
2% was in base surge
PREDICTED
OBSERVED
At 24 hours, 52% of gamma radiation
was neutron induced tungsten pusher
DOSE RATE AT H + 1, R/hr
DISTANCE, NAUTICAL MILES
10^2
10
1
10^{-1}
10^{-2}
0
10
20
30
40
50
60
70

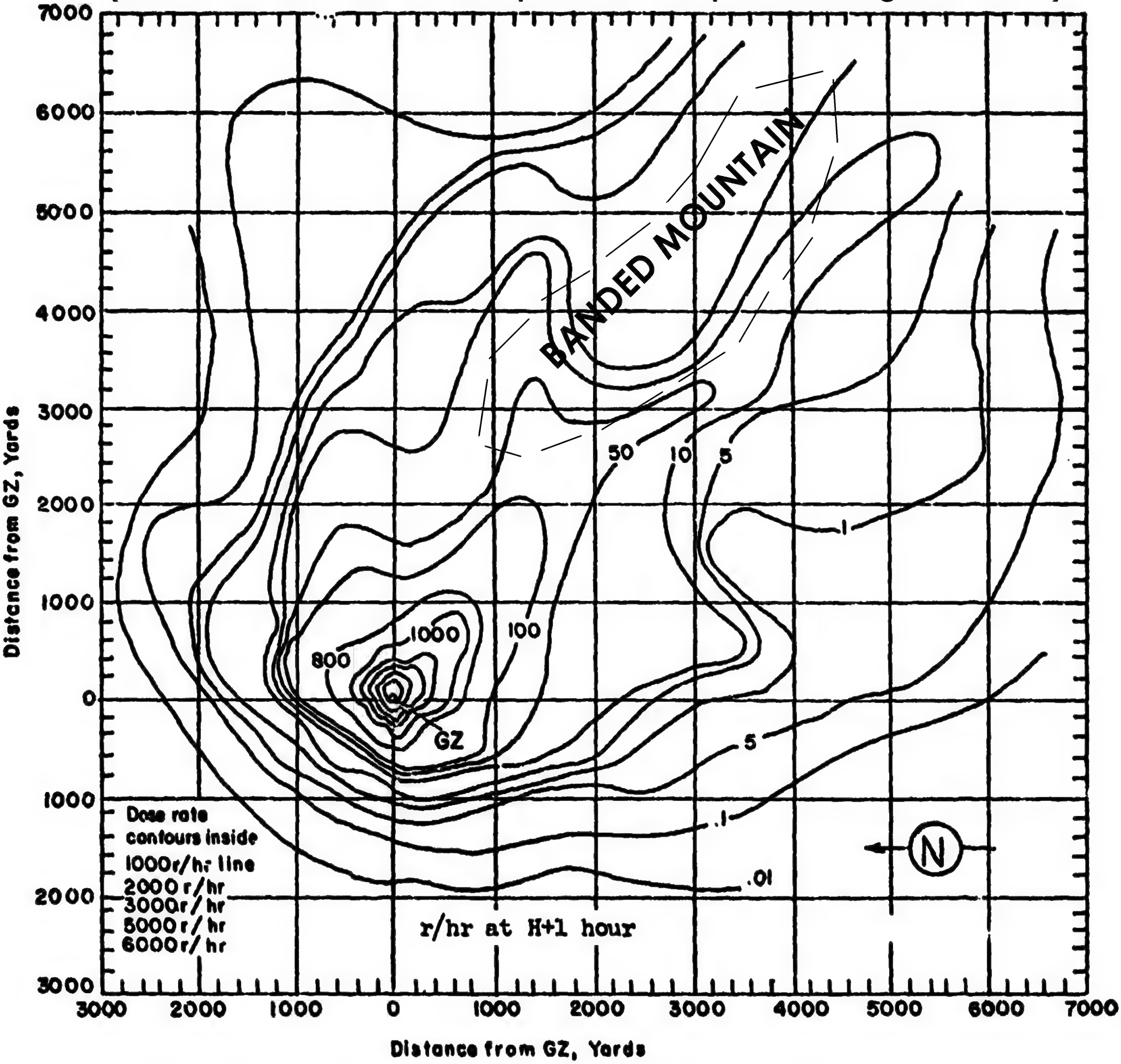
TEAPOT-ESS: 5 SEC. (1.2 KT NUCLEAR TEST AT 67 FEET DEPTH, NEVADA, 23 MARCH 1955)



TEAPOT-ESS: 3 MIN. (1.2 KT NUCLEAR TEST AT 67 FEET DEPTH, NEVADA, 23 MARCH 1955)

TEAPOT - Ess 23 Mar 1955 **1.2 kt at 67 ft depth, Nevada soil, 20 mph wind**

(Fallout on Banded Mountain spread over slopes, reducing dose rates.)

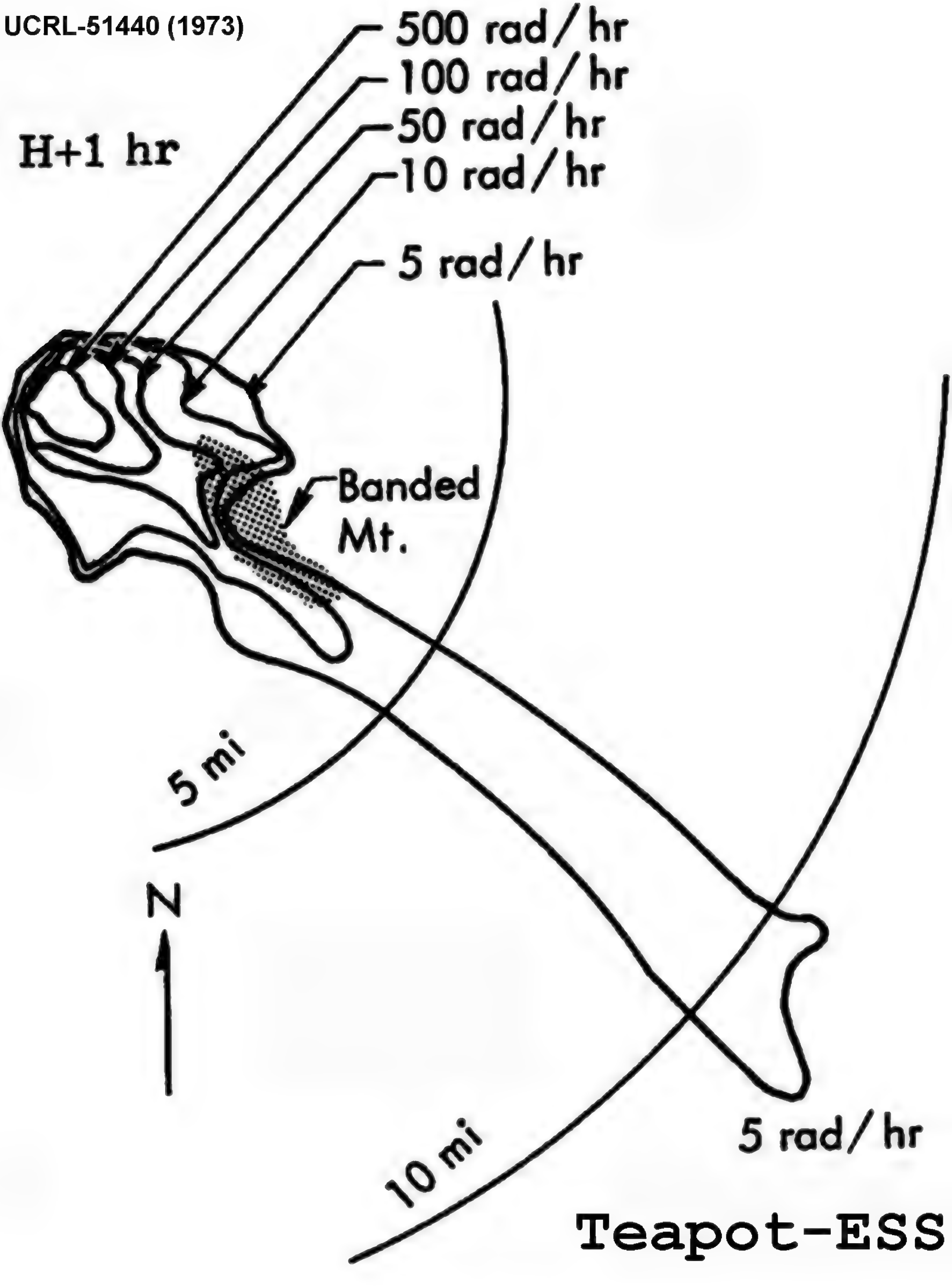


CRATER DATA: Diameter: 292 ft
Depth: 96 ft
Maximum Dose Rate: 6000 r/hr at H+1 hour at crater lip

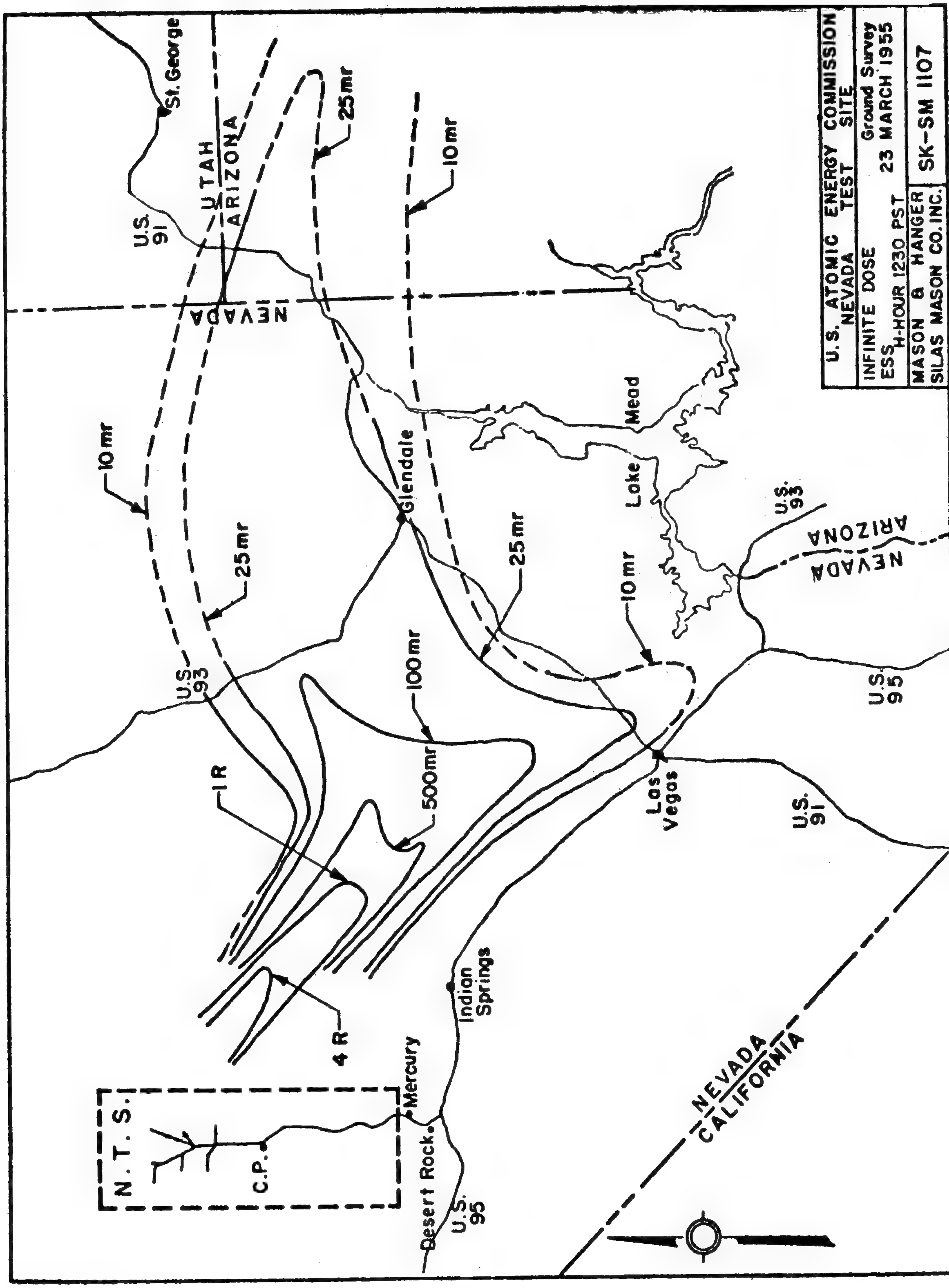
HEIGHT OF BURST: -67 ft

CLOUD TOP HEIGHT: 12,000 ft MSL

UCRL-51440 (1973)



Teapot-ESS


U.S. ATOMIC ENERGY COMMISSION
NEVADA TEST SITE
INFINITE DOSE
ESS
Ground Survey
H-HOUR 1230 PST
23 MARCH 1955
MASON & HANGER
SILAS MASON CO. INC.
SK-SM 1107
St. George
UTAH
ARIZONA
NEVADA
U.S. 91
U.S. 93
U.S. 95
Lake Mead
Glendale
Las Vegas
Indian Springs
Mercury
Desert Rock
C.P.
N.T.S.
10 mr
25 mr
100 mr
500 mr
1 R
4 R
NEVADA
CALIFORNIA

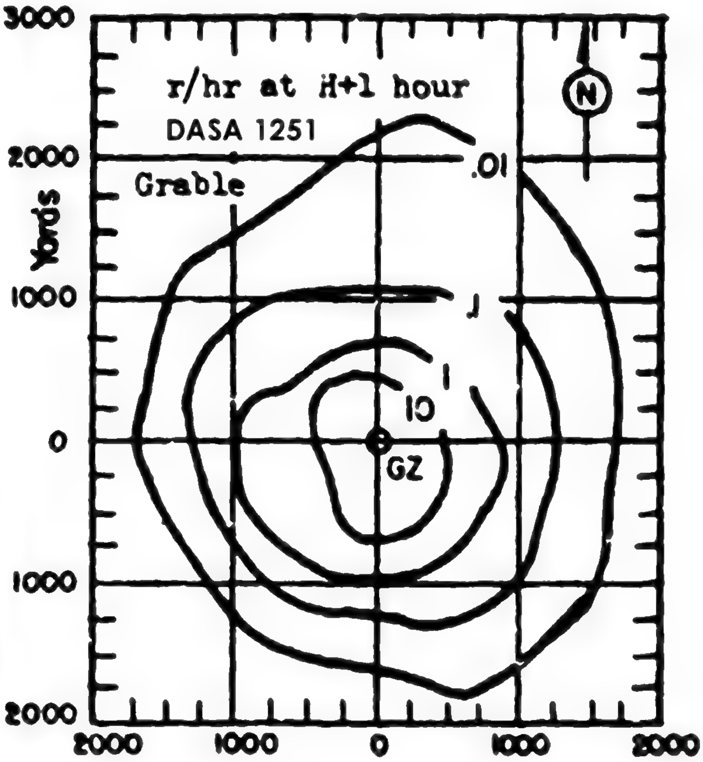
(May-June 1957 Hearings before Joint Committee on Atomic Energy)

STATEMENT OF DR. W. W. KELLOGG, RAND CORP.

Atmospheric Transport and Close-in Fallout of Radioactive Debris From Atomic Explosions

In the case of an air burst in which the white-hot fireball never reaches the surface, the radioactive fission products never come into close contact with the surface material; they remain as an exceedingly fine aerosol. At first sight this might be thought to be an oversimplification, since there have been many cases in which the fireball never touched the ground, but the surface material was observed to have been sucked up into the rising atomic cloud. Actually, however, in such cases a survey of the area has shown that there has been a negligible amount of radioactive fallout on the ground. Though tons of sand and dust may have been raised by the explosion, they apparently did not become contaminated by fission products.

The explanation for this curious fact prabably lies in a detailed consideration of the way in which the surface material is sucked up into the fireball of an air burst. Within a few seconds from burst time, the circulation in the atomic fireball develops a toroidal form, with an updraft in the middle and downdraft around the outside. Most of the fission products are then confined to a dough-nut-shaped region, and may be thought of as constituting a smoke ring. When the surface debris is carried into the fireball a few seconds after the detonation, it passes up along the axis of the cloud, through the middle, and can often be seen to cascade back down around the outside of the cloud. In its passage through the cloud, it has passed around the radioactive smoke ring but has never mixed with it.



15 kt UPSHOT-KNOTHOLE - Grable 25 May 1953

FIREBALL Radius at 2nd maximum: 557.6

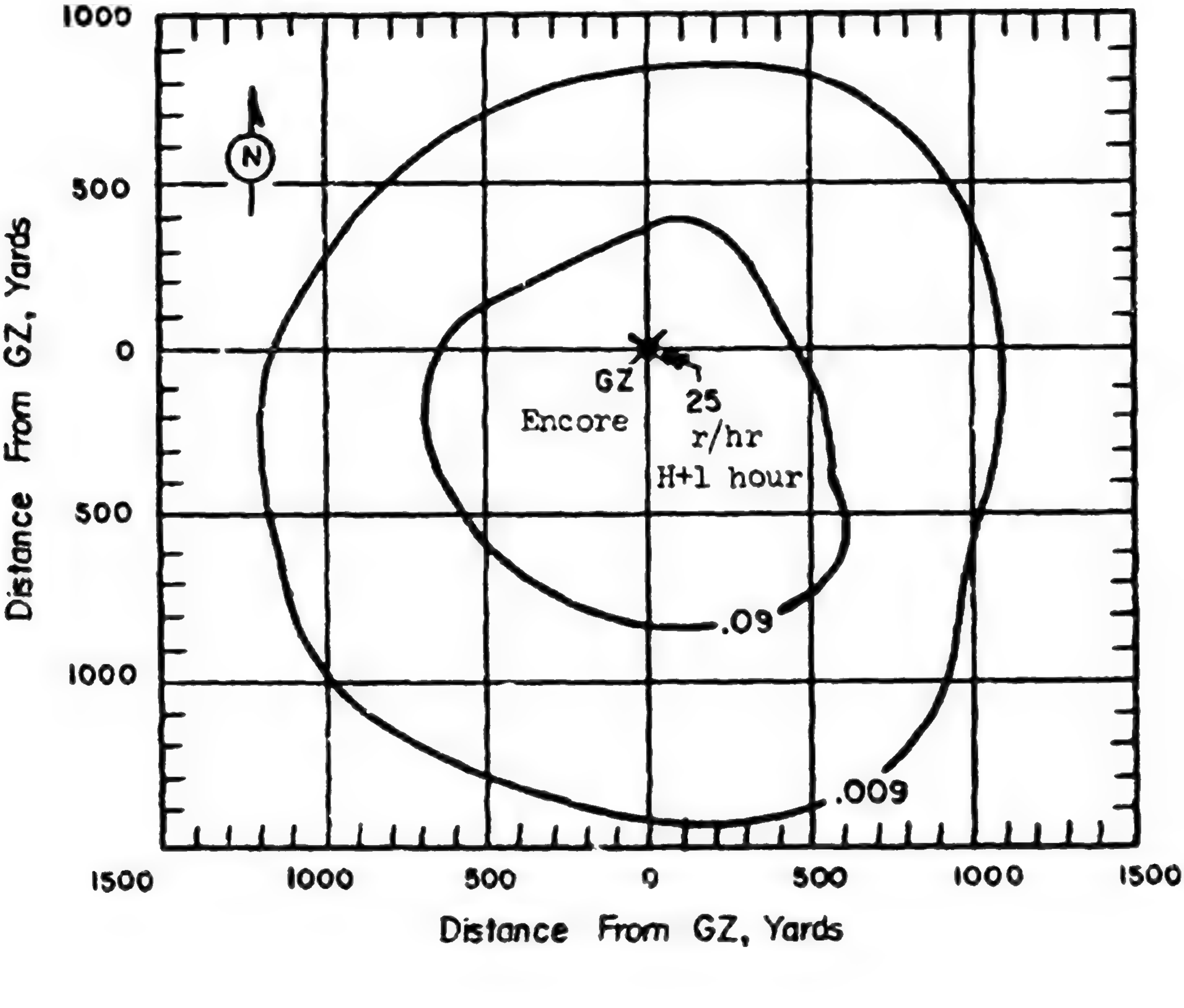
HEIGHT OF BURST: 524 ft

TYPE OF BURST AND PLACEMENT: Airburst of guntype weapon

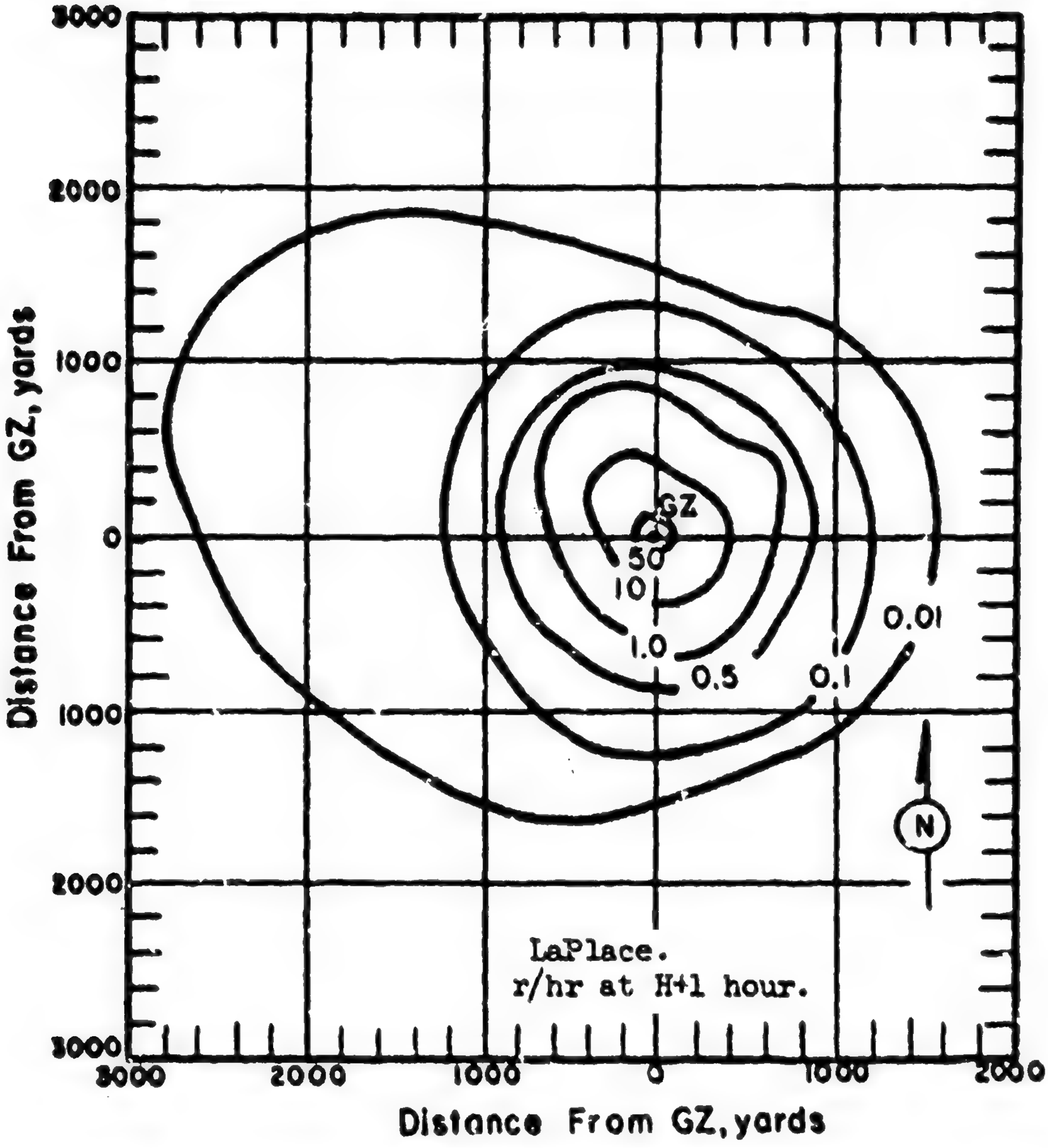
CLOUD TOP HEIGHT: 35,000 ft MSL

CLOUD BOTTOM HEIGHT: 23,000 ft MSL

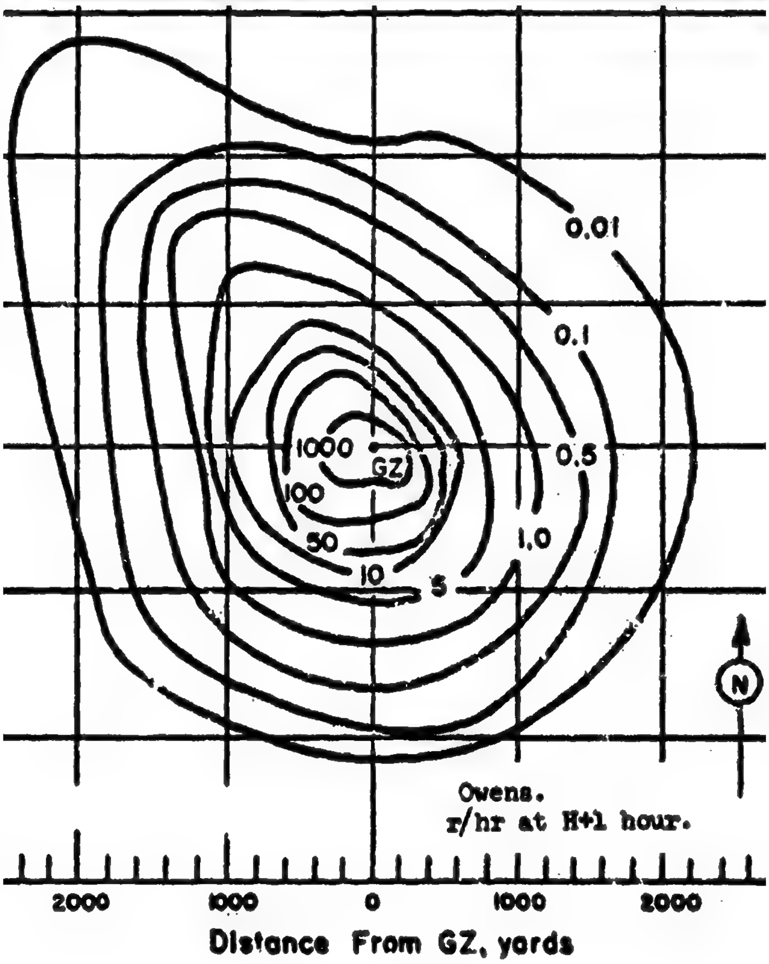
ENCORE, 27 KT AIR BURST AT 2,423 FT



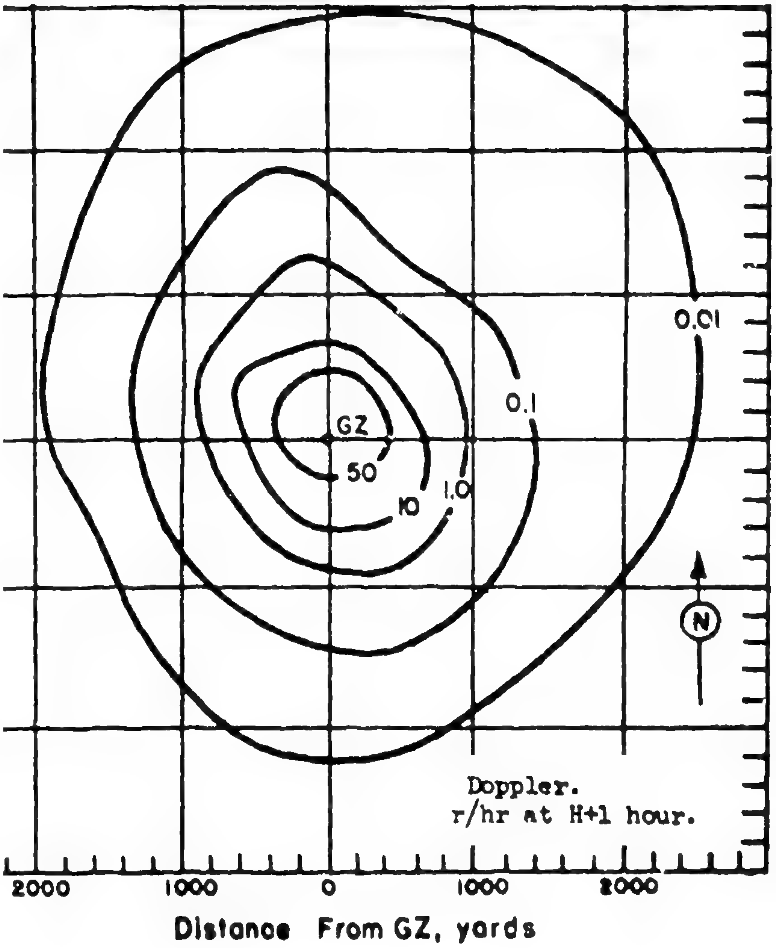
LAPLACE 1 kt 750 ft balloon air burst



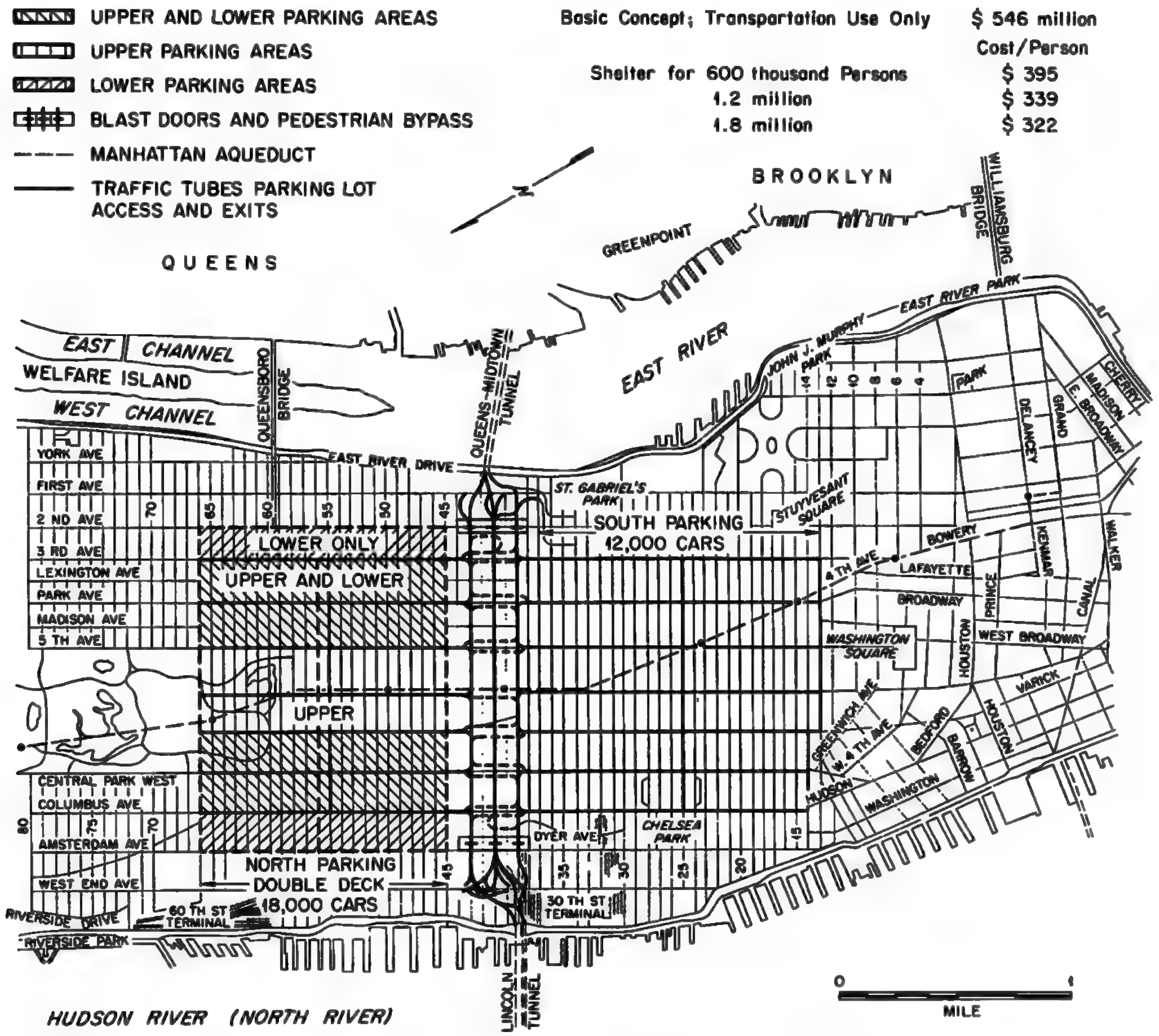
OWENS 9.7 kt 500 ft balloon air burst



DOPPLER 11 kt 1500 ft balloon air burst



Harold F. Perla and Harry Haller (Holmes and Narver, Inc.), <u>Engineering Study of Underground Highway and Parking Garage and Blast Shelter</u>, ORNL-TM-1381 (March 1966).



Proposed Dual-Use Shelters for Manhattan.

(Interconnecting Traffic Tubes and Underground Parking Areas)

Report on a Study of Non-Military Defense

July 1, 1958

Report R-322-RC

THE RAND CORPORATION

II. Population Shelters

The first big question that must be raised about non-military defense is whether people can in fact be protected from modern nuclear weapons. Protection involves not only provision of shelters capable of withstanding blast and fallout effects, but also arrangements for getting people into the shelters in response to different kinds of warnings. It should be stated at the beginning that it is impossible to provide reliable protection for all the population, and that the fraction of the population effectively protected depends greatly on the essentially uncertain nature of the enemy attack. There appear to be a number of possibilities for protective systems, however, and under plausible assumptions about the enemy attack and the civilian response, significant—and in some cases dramatic—reductions in civilian casualties appear to be obtainable.

TYPES OF SHELTERS

Improvised fallout shelters, even if only capable of reducing radiation to 1/20 or 1/30 of the radiation outside, could have a significant effect in reducing casualties among people outside the areas of blast damage. There seem to be many possibilities of identifying and preparing such shelters in existing buildings in small cities and towns. For example, a location in the center of the basement of a 40,000-square-foot building (a typical large office, store, or school building) may provide an attenuation to about 1/80. Moreover, a foot of earth gives a reduction to about 1/30, and sandbags distributed in advance could be quickly filled and placed to provide this type of shielding. Even buildings whose structural characteristics provide smaller attenuation factors could be quite useful, with arrangements for washing down or sweeping the roofs and surrounding areas (exposure to carry out the decontamination being rationed among the shelter inhabitants).

Table 2

ESTIMATED LONG-TERM RADIATION AFTER VARIOUS ATTACKS

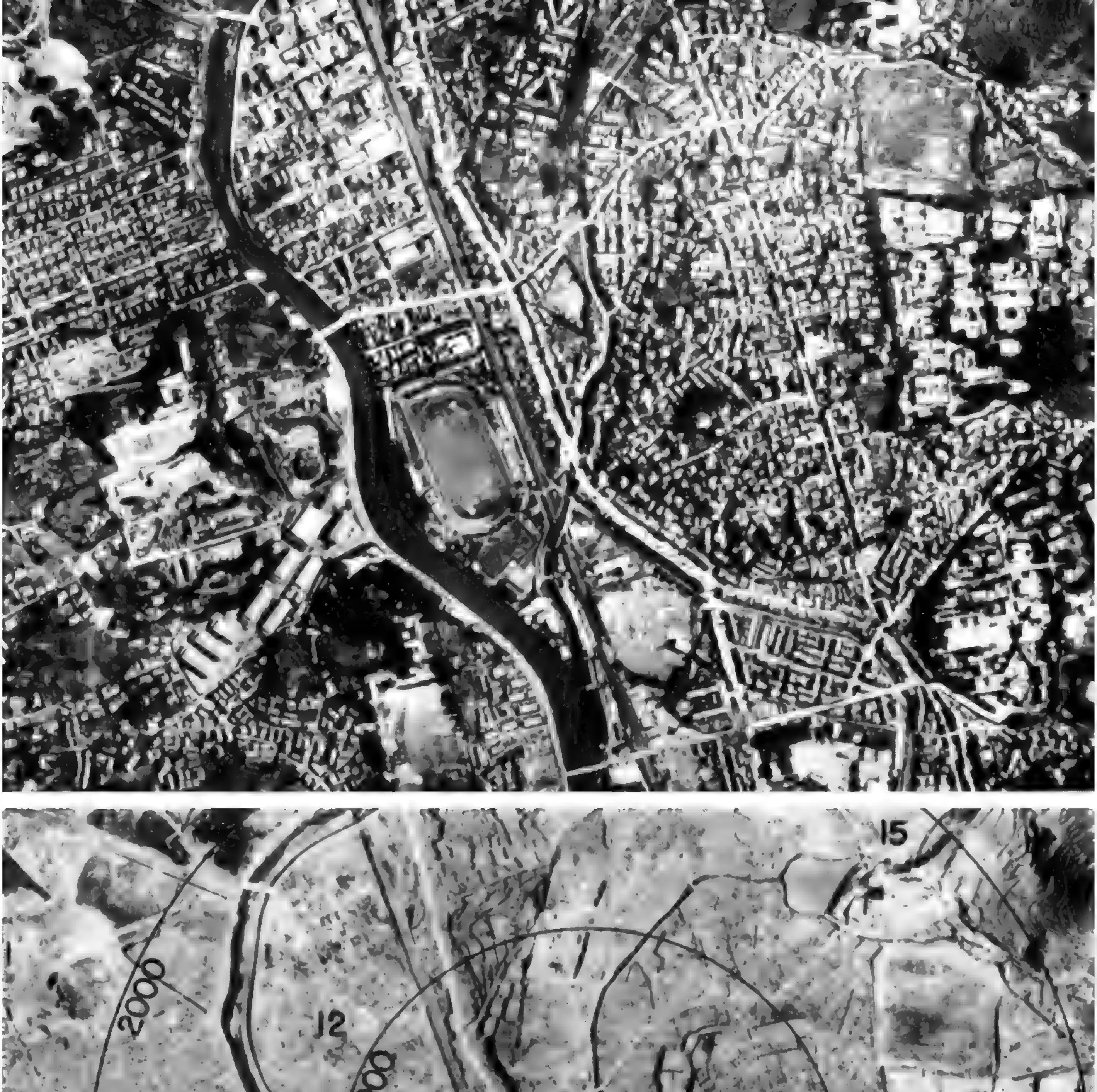
1500 MEGATONS OF FISSION PRODUCTS (50-CITY ATTACK)

	Average	Maximum	Minimum
Total fallout (kilotons per square mile)	0.4	8.3	0.003
Radiation rate after 90 days with countermeasures[a] (milliroentgens per hour)	0.46	10	0.0035
Cumulative lifetime exposure[a] (roentgens)	3.4	73	0.026
Strontium-90 fallout (curies per square mile)	40	830	0.3
Cumulative lifetime concentration in bone without countermeasures (microcuries)	2	42	0.015

20,000 MEGATONS OF FISSION PRODUCTS (AREA ATTACK)

	Average	Maximum	Minimum
Total fallout (kilotons per square mile)	5.3	36	0.04
Radiation rate after 90 days with countermeasures[a] (milliroentgens per hour)	6.5	43	0.049
Cumulative lifetime exposure[a] (roentgens)	48	310	0.36
Strontium-90 fallout (curies per square mile)	530	3600	4
Cumulative lifetime concentration in bone without countermeasures (microcuries)	26	180	0.2

[a] Assumes that radiation rates are reduced to 1/100 of the level computed with the $t^{-1.2}$ formula, because of decontamination, shielding and time-rationing, and inaccuracy in the formula.



Area around ground zero at Nagasaki before and after explosion (1,000-foot radius circles are shown).

THE EFFECTS OF THE ATOMIC BOMBS AT HIROSHIMA AND NAGASAKI

REPORT OF THE BRITISH MISSION TO JAPAN

PUBLISHED
FOR THE HOME OFFICE AND THE AIR MINISTRY BY
HIS MAJESTY'S STATIONERY OFFICE
LONDON
1946

40. The provision of air raid shelters throughout Japan was much below European standards. Those along the verges of the wider streets in Hiroshima were comparatively well constructed : they were semi-sunk, about 20 ft. long, had wooden frames, and 1 ft. 6 ins. to 2 ft. of earth cover. One is shown in photograph 17. Exploding so high above them, the bomb damaged none of these shelters.

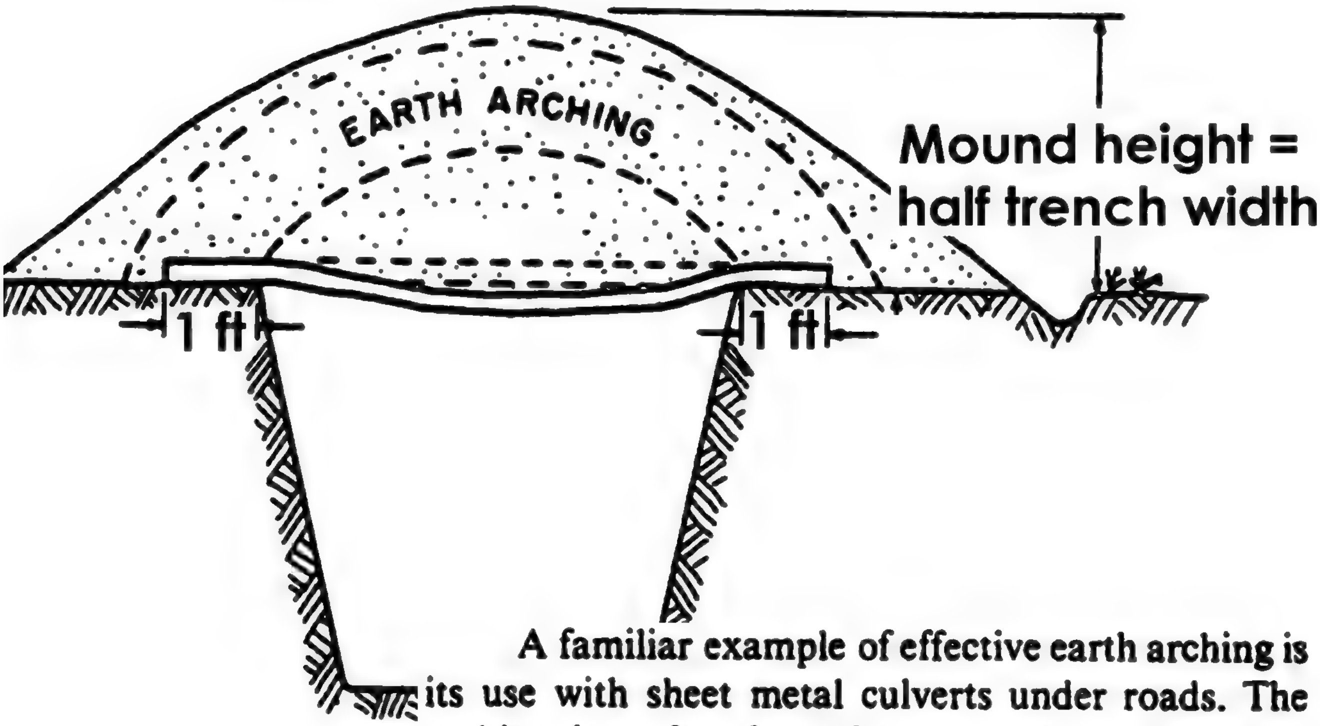
41. In Nagasaki there were no communal shelters except small caves dug in the hillsides. Here most householders had made their own backyard shelters, usually slit trenches or bolt holes covered with a foot or so of earth carried on rough poles and bamboos. These crude shelters, one of which is shown in photograph 18, nevertheless had considerable mass and flexibility, qualities which are valuable in giving protection from blast. Most of these shelters had their roofs forced in immediately below the explosion ; but the proportion so damaged had fallen to 50 per cent. at 300 yards from the centre of damage, and to zero at about ½ mile.

42. These observations show that the standard British shelters would have performed well against a bomb of the same power exploded at such a height. Anderson shelters, properly erected and covered, would have given protection. Brick or concrete surface shelters with adequate reinforcement would have remained safe from collapse. The Morrison shelter is designed only to protect its occupants from the debris load of a house, and this it would have done. Deep shelters such as the refuge provided by the London Underground would have given complete protection.

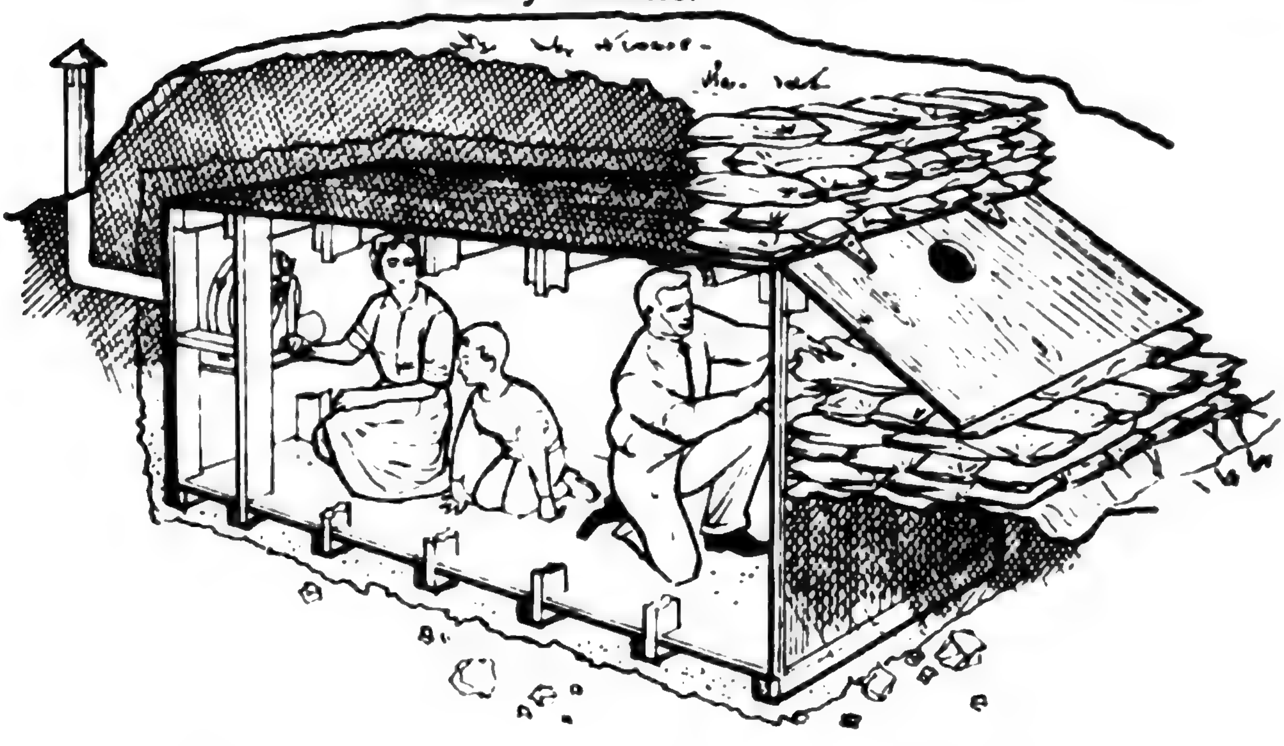
Photo No. 17. HIROSHIMA. Typical, part below ground, earth-covered, timber framed shelter 300 yds. from the centre of damage, which is to the right. In common with similar but fully sunk shelters, none appeared to have been structurally damaged by the blast. Exposed woodwork was liable to "flashburn." Internal blast probably threw the occupants about, and gamma rays may have caused casualties.

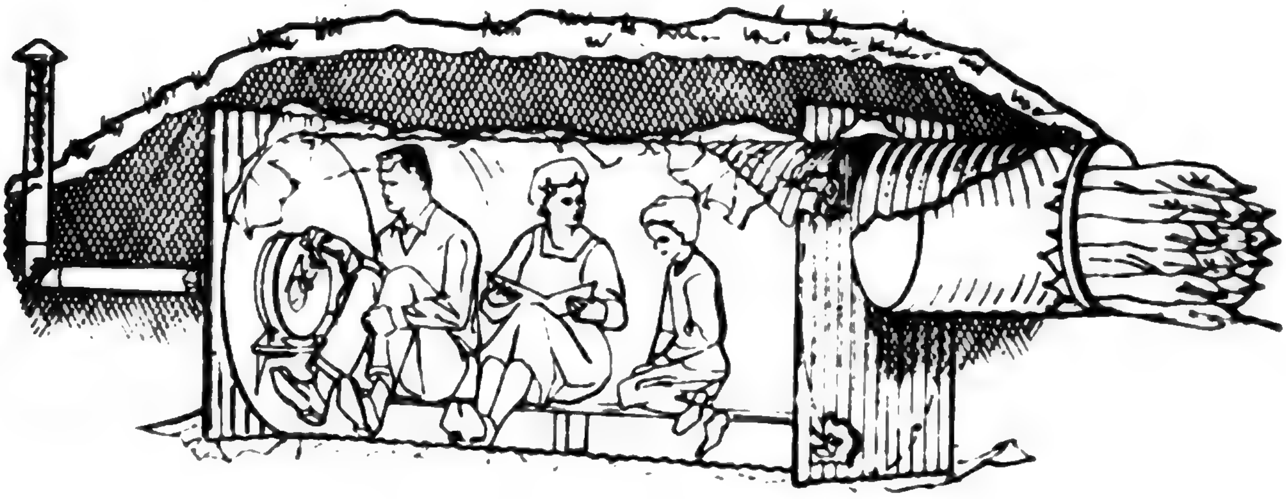
Photo No. 18. NAGASAKI. Typical small earth-covered back yard shelter with crude wooden frame, less than 100 yds. from the centre of damage, which is to the right. There was a large number of such shelters, but whereas nearly all those as close as this one had their roofs forced in, only half were damaged at 300 yds., and practically none at half a mile from the centre of damage.

EARTH ARCHING USED TO STRENGTHEN SHELTERS



A familiar example of effective earth arching is its use with sheet metal culverts under roads. The arching in a few feet of earth over a thin-walled culvert prevents it from being crushed by the weight of heavy vehicles.





UK NATIONAL ARCHIVES: ES 5/2
ANDERSON SHELTER TESTS AGAINST 25 KT NUCLEAR NEAR SURFACE BURST (2.7 METRES DEPTH IN SHIP)
AWRE-T1/54, 27 Aug. 1954

SECRET—GUARD

ATOMIC WEAPONS RESEARCH ESTABLISHMENT
(formerly of Ministry of Supply)

SCIENTIFIC DATA OBTAINED AT OPERATION HURRICANE
(Monte Bello Islands, Australia—October, 1952)

$$p = \frac{130 \times 10^9}{R^3} + \frac{7 \cdot 7 \times 10^6}{R^2} + \frac{13 \cdot 5 \times 10^3}{R}$$

p is the maximum excess pressure in p.s.i. and R is the distance in feet

Fig. 12.1, Andersons at 1380 ft range from bomb ship shown in the photo, moored 400 yards off shore.

Left: Fig. 12.3, Andersons at 1800 ft after burst. Right: Fig. 12.4, Andersons protected by blast walls at 2760 ft.

12.1. *Blast Damage to Anderson Shelters*

At 1,380 feet, Fig. 12.1, parts of the main structure of the shelters facing towards and sideways to the explosion were blown in but the main structure of the one facing away from the explosion was intact, and would have given full protection. At 1,530 feet, Fig. 12.2, the front sheets of the shelter facing the explosion were blown into the shelter but otherwise the main structures were more or less undamaged, as were those at 1,800 feet, Fig. 12.3.

At 2,760 feet, Fig. 12.4, some of the sandbags covering the shelters were displaced and the blast walls were distorted whilst at 3,390 feet, Fig. 12.5, the effect was quite small. At these distances, the shelters were not in direct view of the explosion owing to intervening sandhills.

13. The Penetration of the Gamma Flash

13.1. *Experiments on the Protection from the Gamma Flash afforded by Slit Trenches*

13.1.1. The experiments described in this section show that slit trenches provide a considerable measure of protection from the gamma flash. From the point of view of Service and Civil Defence authorities this is one of the most important results of the trial.

13.1.2. Rectangular slit trenches 6 ft. by 2 ft. in plan and 6 ft. deep were placed at 733, 943 and 1,300 yards from the bomb and circular fox holes 2 ft. in radius and 6 ft. deep were placed at 943 and 1,300 yards.

The doses received from the flash were measured with film badges and quartz-fibre dosimeters in order to determine the variation of protection with distance, with depth and with orientation of the trench and the relative protection afforded by open and covered trenches.

In general, the slit trenches were placed broadside-on to the target vessel but at 1,300 yards one trench was placed end-on. Two trenches, one at 733 and one at 943 yards were covered with the equivalent of 11 inches of sand.

Table 13.1

Variation of Gamma Flash Dose on Vertical Axis of Trench

Type of trench	Rectangular broadside-on open			Rectangular end-on open	Circular open		Rectangular broadside-on covered	
Distance (yards) ...	1,300	943	733	1,300	1,300	943	943	733
Surface dose (Roentgens)	300	3,000	14,000	300	300	3,000	3,000	14,000
Depth below ground level (inches)								
6 ...	150	1,000	—	230	214	1,200	(75)	—
12 ...	75	430	—	150	120	545	47·6	—
24 ...	33·3	150	584	60	54·5	188	25	(140)
36 ...	23	70	216	31·6	30	86	13	(56)
48 ...	(20)	43	100	20	17·7	48·5	7·7	(31)
60 ...	—	(37·5)	61	13·6	10·7	(33·3)	5	(23)
72 ...	—	—	(46·7)	(8·6)	7	—	(3·5)	—

Entries in brackets are extrapolations or estimates.

Air raid trench
1940

UK NATIONAL ARCHIVES: HO225/16 (1950)

THE NUMBER OF ATOMIC BOMBS EQUIVALENT TO THE LAST WAR AIR ATTACKS ON GREAT BRITAIN AND GERMANY

Summary

During the last war, a total of 1,300,000 tons* of bombs were dropped on Germany by the Strategic Air Forces. If there were no increase in aimi[ng] accuracy, then to achieve the same total amount of material damage (to houses, industrial and transportation targets, etc.) would have required the use of over 300 atomic bombs together with some 500,000 tons of high explosive and incendiary bombs for targets too small to warrant the use of an atomic bomb. Increases in accuracy could cause a substantial reduction in this figure of 300 atomic bombs, to as few as 100-150 bombs for very accurate attacks.

CD 2333

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CD/SA 12
Copy. NO 5.

HOME OFFICE

OFFICE OF THE CHIEF SCIENTIFIC ADVISER

A COMPARISON BETWEEN THE NUMBER OF PEOPLE KILLED PER TONNE OF BOMBS DURING WORLD WAR I AND WORLD WAR II

BOMB SIZES

=> ≈ 175 kg

For World War II the average bomb weight was between 150 - 200 kg. (R.C. 268, Table 6), whereas for World War I the majority of bombs were 12 or 50 kg.

TABLE 5

Relative safeties in World War II deduced from population and casualty distribution

	In the open	Under cover	In shelter
Population exposure	5%	60%	35%
Location people killed	19%	62%	19%
Relative safety	72%	20%	10%
RELATIVE DANGER!			

(1) A house about 3½ times as safe as in the open.
(2) A shelter about twice as safe as a house.

Table 6 also shows the location of killed which is implied by each of the possible population exposures. The only evidence available on this point is that, for the day raid on June 13th, 1916, in which the total number killed was 59, 69.5% of the people killed in the City were in the open.

HOME OFFICE

AIR RAID PRECAUTIONS

DIRECTIONS FOR THE ERECTION AND SINKING OF THE GALVANISED CORRUGATED STEEL SHELTER

(ANDERSON SHELTER)

February 1939

London family who survived in Anderson shelter during Blitz, when the shelter absorbed the blast (earth was blown off) in 1940

A.R.P. (O) 10

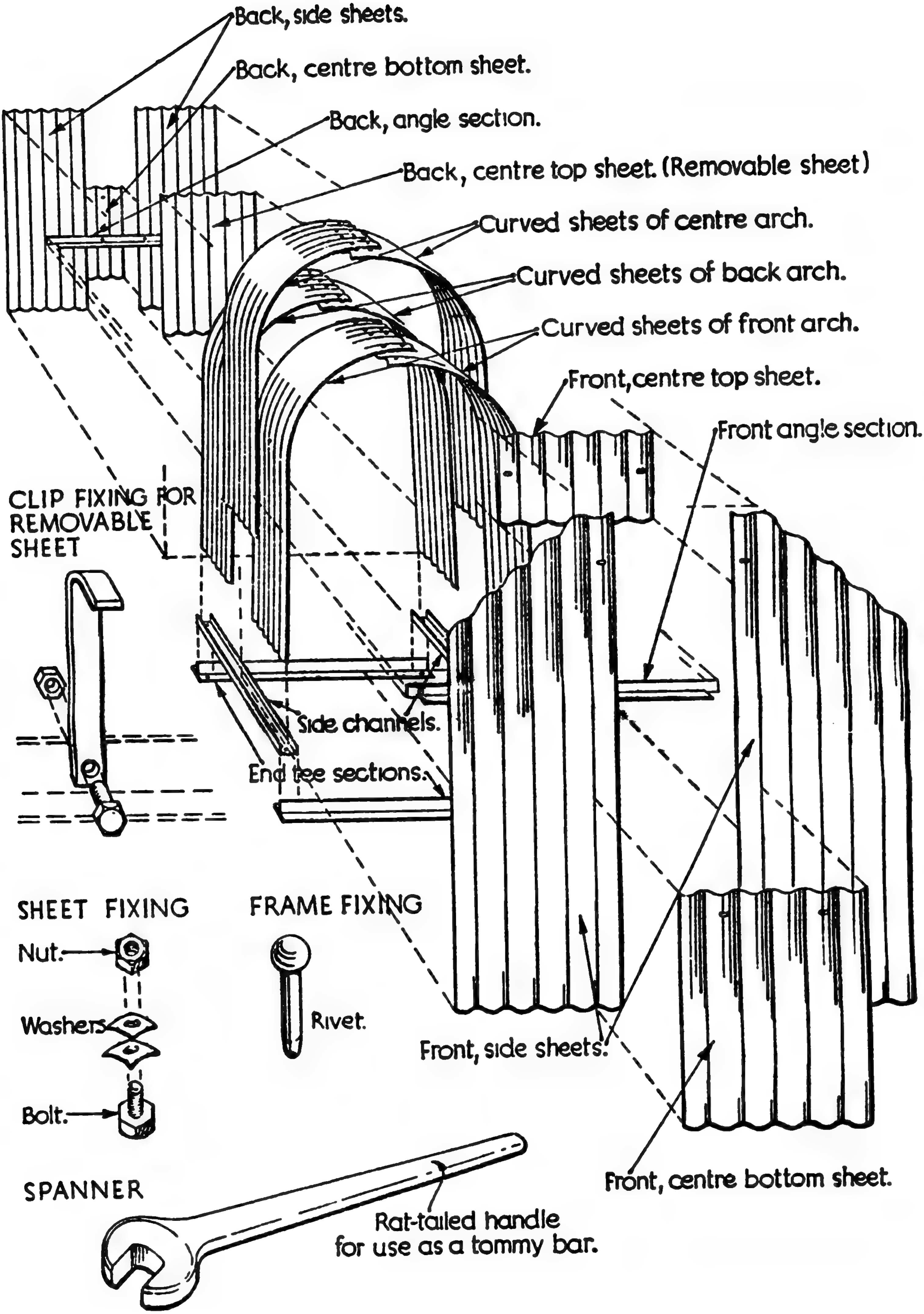


Fig. 3.—The Individual Parts.

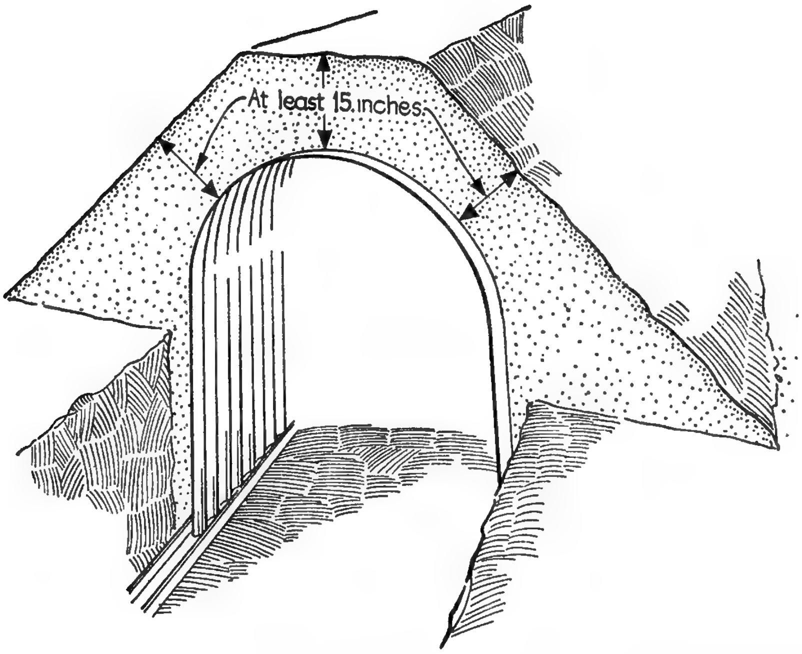


FIG. 4.—STAGE 12. COVERING THE SHELTER WITH EARTH.

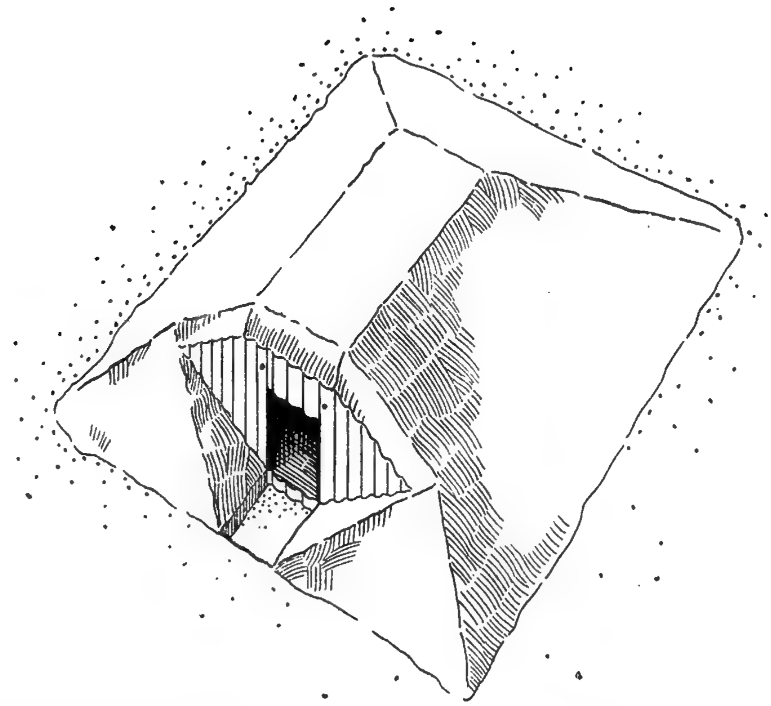


FIG. 4.—STAGE 13. THE SHELTER COMPLETE WITH EARTH COVER.

Anderson shelter survives hit: Norwich 27 April 1942

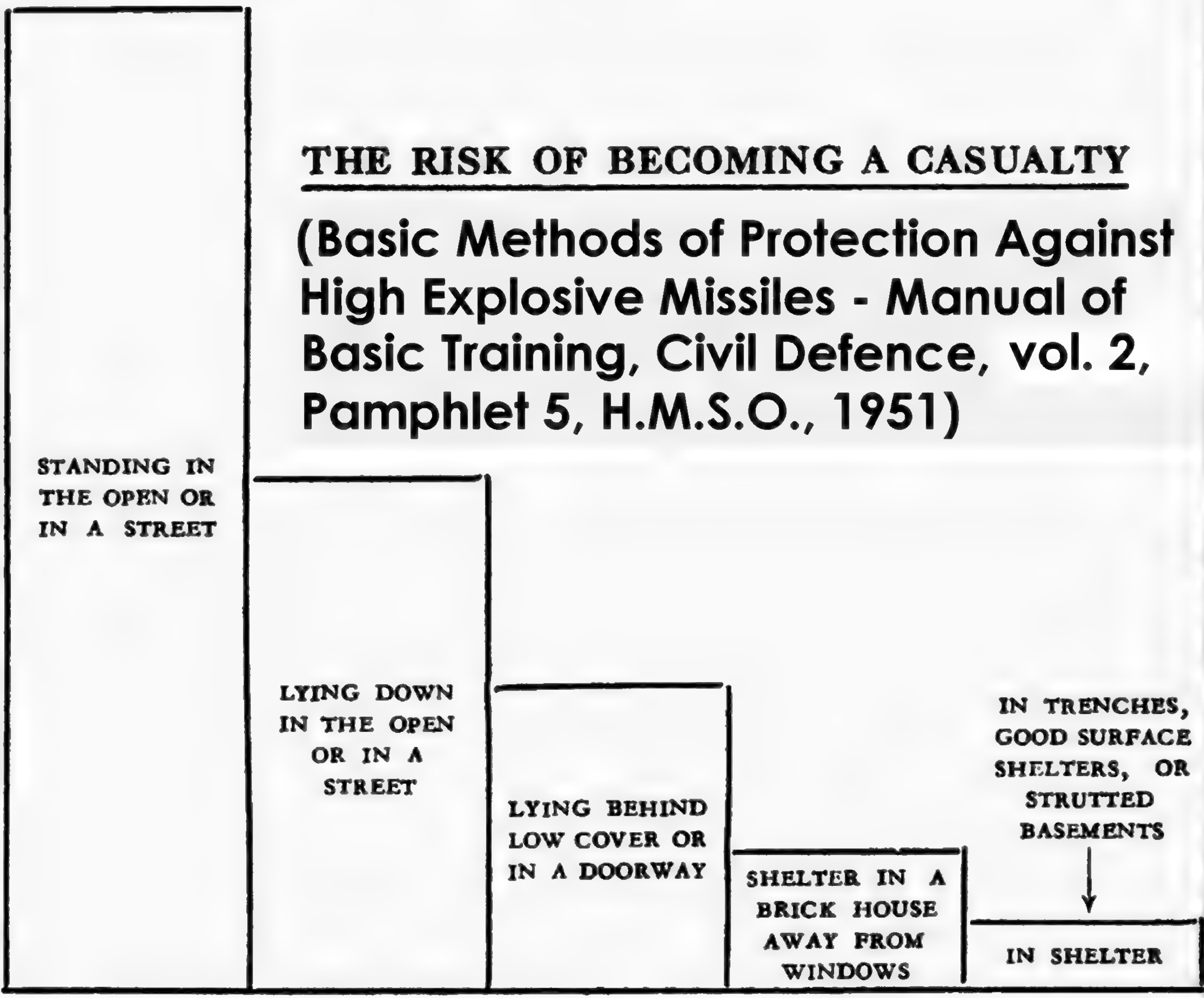
Anderson shelter survives, Croydon, October 1940

Anderson shelters absorbed the blast energy and were damaged, saving lives.

It cannot be too strongly emphasised that it is most important, from the point of view of reducing casualties as a whole, for everyone in an area under attack to make use of any shelter that is available. Recent research has shown that there would be less fatal casualties if everyone were in relatively poor shelter than if half the population were in shelter twice as good and the other half remained in the open.

THE RISK OF BECOMING A CASUALTY

(Basic Methods of Protection Against High Explosive Missiles - Manual of Basic Training, Civil Defence, vol. 2, Pamphlet 5, H.M.S.O., 1951)



Proof that the Anderson garden shelter could withstand a house collapsing on it can be seen in this picture. Mr. and Mrs. Clague bless their insistence on 'going to ground' when their homes and those of their neighbours were reduced to rubble.

18 June 1941

Anderson shelter survives at Latham Street, Poplar, London, 1941:

And They Came Out of It Alive...

The edge of this bomb crater, 30ft. deep, in a household garden near London, is only 4ft. from the Anderson shelter. But the two people in the shelter during London's six-hour raid—Mrs. Clark and Miss Clark—were unhurt. You see Miss Clark in the picture examining the damage to the structure.

Daily Mirror
28 Aug 1940

(THIS DOCUMENT IS THE PROPERTY OF HIS BRITANNIC MAJESTY'S GOVERNMENT).

SECRET.

W.P.(G)(41)7. COPY NO. 62

January 15th, 1941.

WAR CABINET.

AIR RAID SHELTER POLICY.

Memorandum by the Minister of Home Security.

6. Shelter in the home: The Anderson shelter was originally intended for indoor use but for a number of reasons including the danger of fire an outdoor variant was adopted. Experience has shown that the objections to the indoor use of the Anderson or somewhat similar shelter are not so serious as was thought and two designs have been produced which can be erected indoors without support. These new types, although they may give slightly less protection than a well covered Anderson shelter out of doors, would fill the needs of a large section of the public, especially the middle class. One design allows the use of the shelter as part of the furniture of the room.

7. I regard shelters of this type as of the first importance and wish to provide them on a big scale. Each shelter will use over 3 cwt. of steel and will allow at a pinch two adults and one to two children to sleep inside. For an outlay of about 65,000 tons of steel, as a first instalment, I could therefore produce 400,000 shelters with accommodation for at least 1,000,000 persons. I should wish to complete such a programme within the first three months of production and thereafter at a similar or increasing rate. From enquiries I believe that manufacture can be arranged provided steel is supplied and if the Cabinet approves my policy I shall require their direction that the steel be made available.

10. Conclusions.

I ask for a general endorsement of the policy I have outlined in this paper and in particular for the agreement of my colleagues:

(i) that proposals for building shelters of massive construction should be rejected;

(ii) that steel should be made available to carry out the programme outlined in paragraph 7 for the provision of steel shelters indoors;

(iii) that the limit of income for the provision of free shelter for insured persons should be raised from £250 to £350 per annum.

H.M.

MINISTRY OF HOME SECURITY.

January 15th, 1941.

Morrison Shelters in Recent Air Raids.

A report of Ministry of Home Security experts on 39 cases of bombing incidents in different parts of Britain covering all those for which full particulars are available in which Morrison shelters were involved shows how well they have stood up to severe tests of heavy bombing.

All the incidents were serious. Many of the incidents involved direct hits on the houses concerned a risk against which it was never claimed these shelters would afford protection. In all of them the houses in which shelters were placed were within the radius of damage by bombs; in 24 there was complete demolition of the house on the shelter.

A hundred and nineteen people were sheltering in these "Morrisons" and only four were killed. So that 115 out of 119 people were saved. Of these only 7 were seriously injured and 14 slightly injured while 94 escaped uninjured. The majority were able to leave their shelters unaided.

November 1940 design by C. A. Joy, M. Inst. Me. & C. E., Bexley Borough Engineer (UK National Archives: HO 205/257)

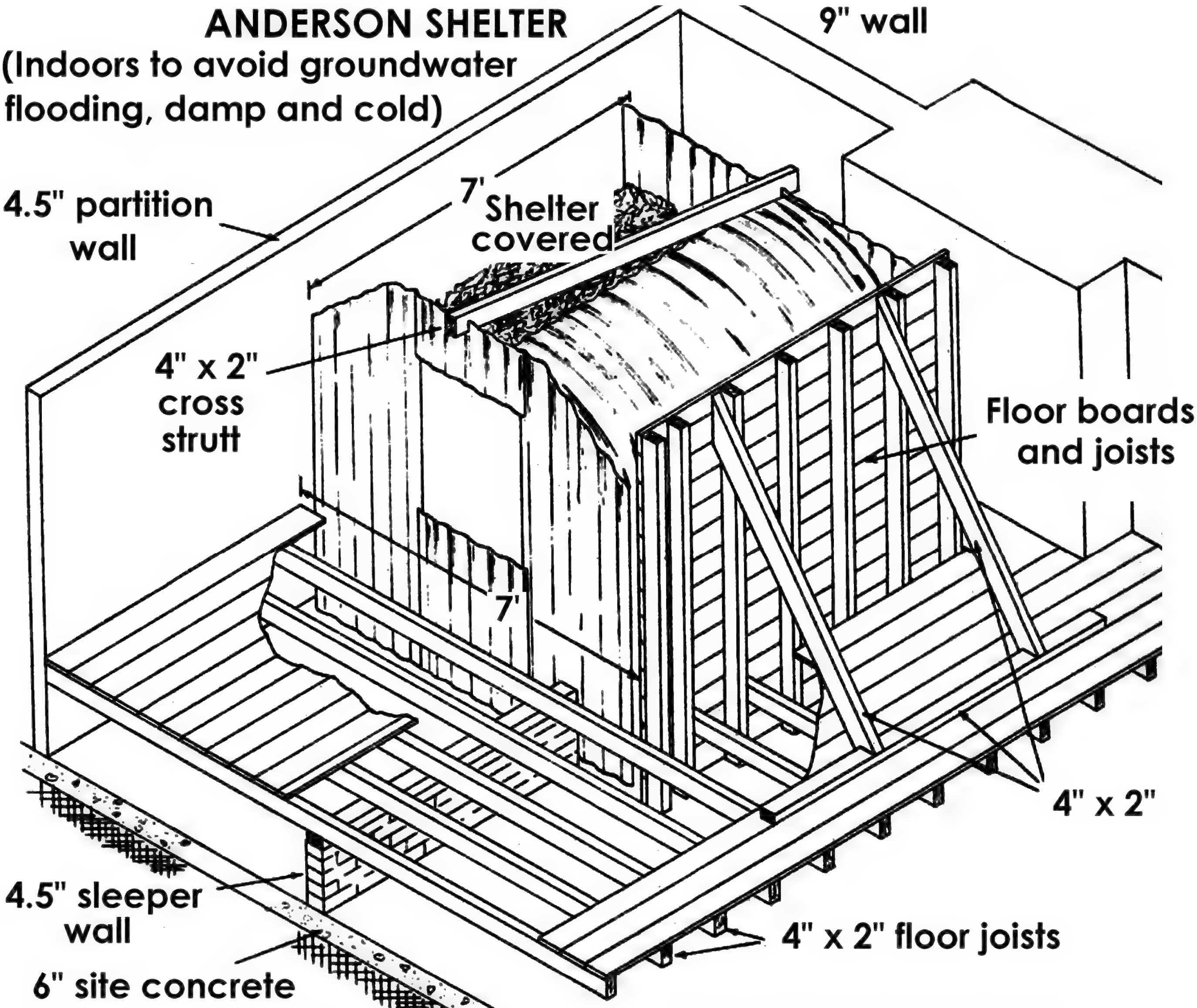
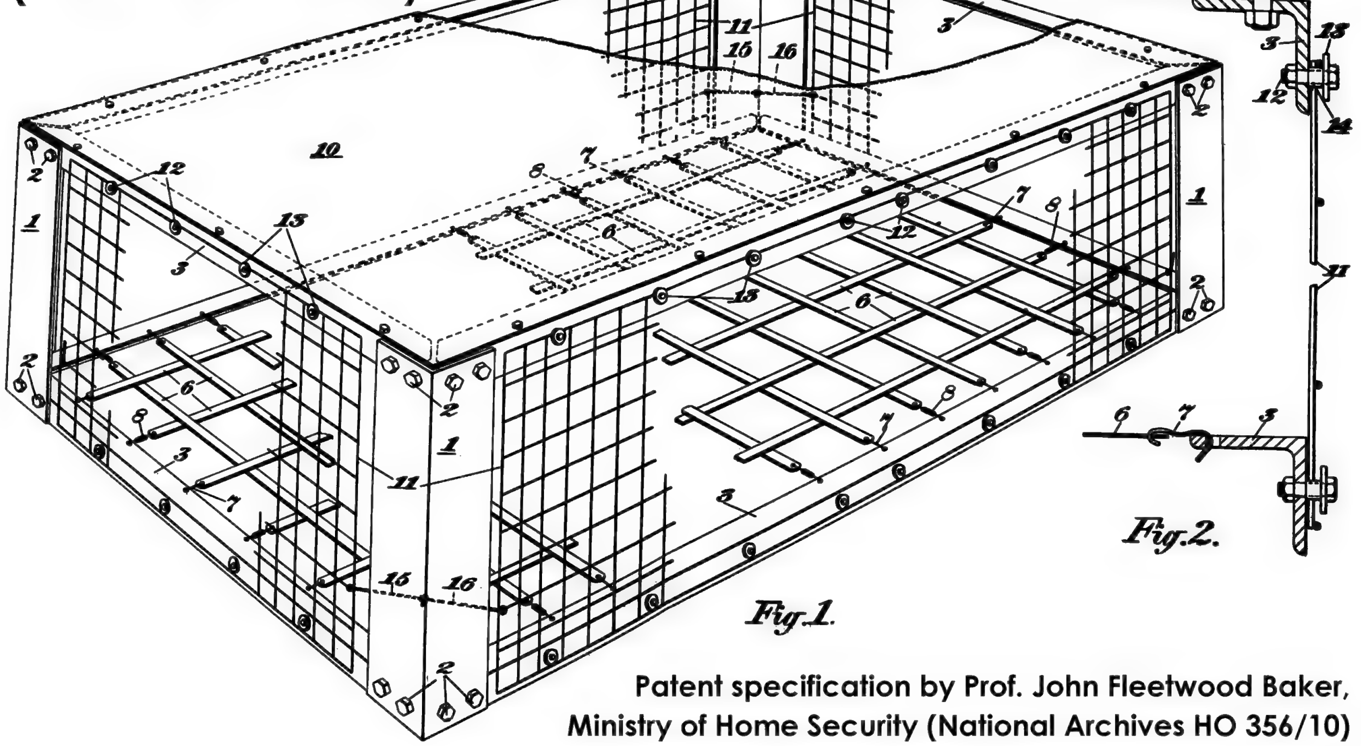
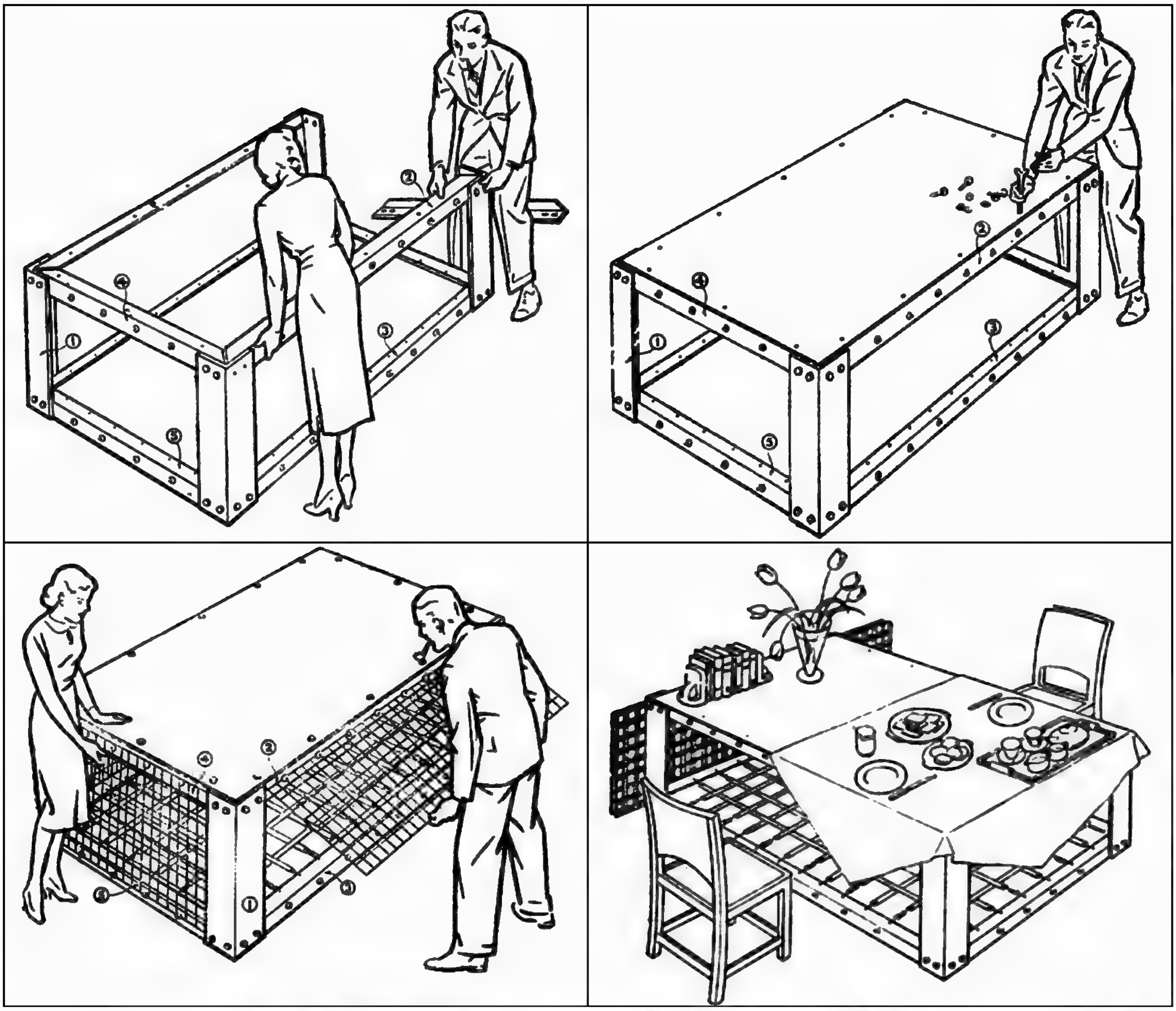


Table shelters allowed escape from any side easily, reducing fire risks

MORRISON SHELTER
(indoor table shelter)



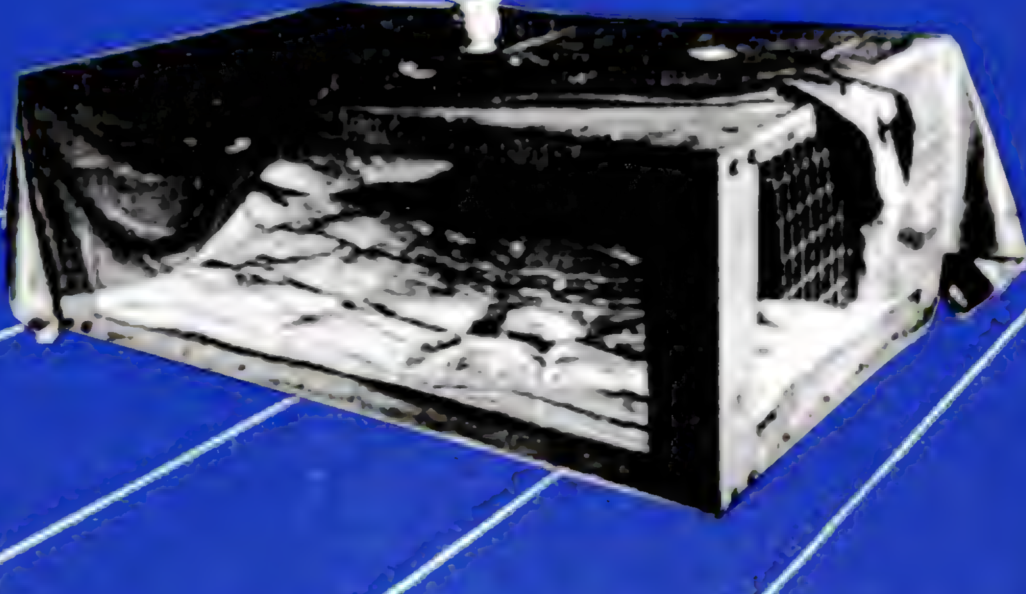
Patent specification by Prof. John Fleetwood Baker, Ministry of Home Security (National Archives HO 356/10)



Structural Defense, 1945, by D. G. Christopherson, Ministry of Home Security, RC 450, (1946); Chapters VIII and IX (Confidential).
Chapter VIII summarizes the literature on the design and types of British shelters and analyzes their effectiveness.

National Archives
HO 195/16

SHELTER at home



3d. ISSUED BY THE MINISTRY OF HOME SECURITY AND PUBLISHED BY H.M. STATIONERY OFFICE

ILLUSTRATION NO. 8.

The house in the upper photograph had a Government steel table shelter in a downstairs room and was blown up to reproduce the effect of a heavy bomb falling near. The whole house collapsed, burying the shelter under débris. In the lower photo the shelter can be seen still intact. It would have been possible for anyone in the shelter to get out unaided.

(Page 11 from the June 1941 UK Ministry of Home Security "Shelter at Home" handbook.)





Morrison shelter survives direct hit in York 1942

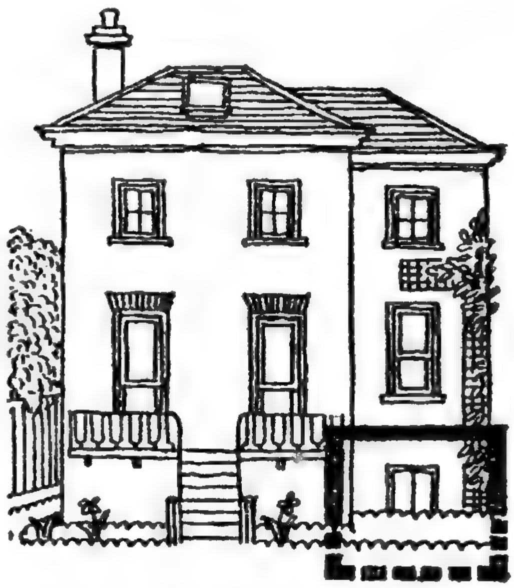
HOME OFFICE

THE PROTECTION OF YOUR HOME AGAINST AIR RAIDS

READ THIS BOOK THROUGH
THEN
KEEP IT CAREFULLY

HOW TO CHOOSE A REFUGE-ROOM

Almost any room will serve as a refuge-room if it is soundly constructed, and if it is easy to reach and to get out of. Its windows should be as few and small as possible, preferably facing a building or blank wall, or a narrow street. If a ground floor room facing a wide street or a stretch of level open ground is chosen, the windows should if possible be specially protected (see pages 30 and 31). The stronger the walls, floor, and ceiling are, the better. Brick partition walls are better than lath and plaster, a concrete ceiling is better than a wooden one. An internal passage will form a very good refuge-room if it can be closed at both ends.



A cellar or basement is the best position for a refuge-room if it can be made reasonably gas-proof

The best floor for a refuge-room

A cellar or basement is the best place for a refuge-room if it can be made reasonably gas-proof and if there is no likelihood of its becoming flooded by a neighbouring river that may burst its banks, or by a burst water-main. If you have any doubt about the risk of flooding ask for advice from your local Council Offices.

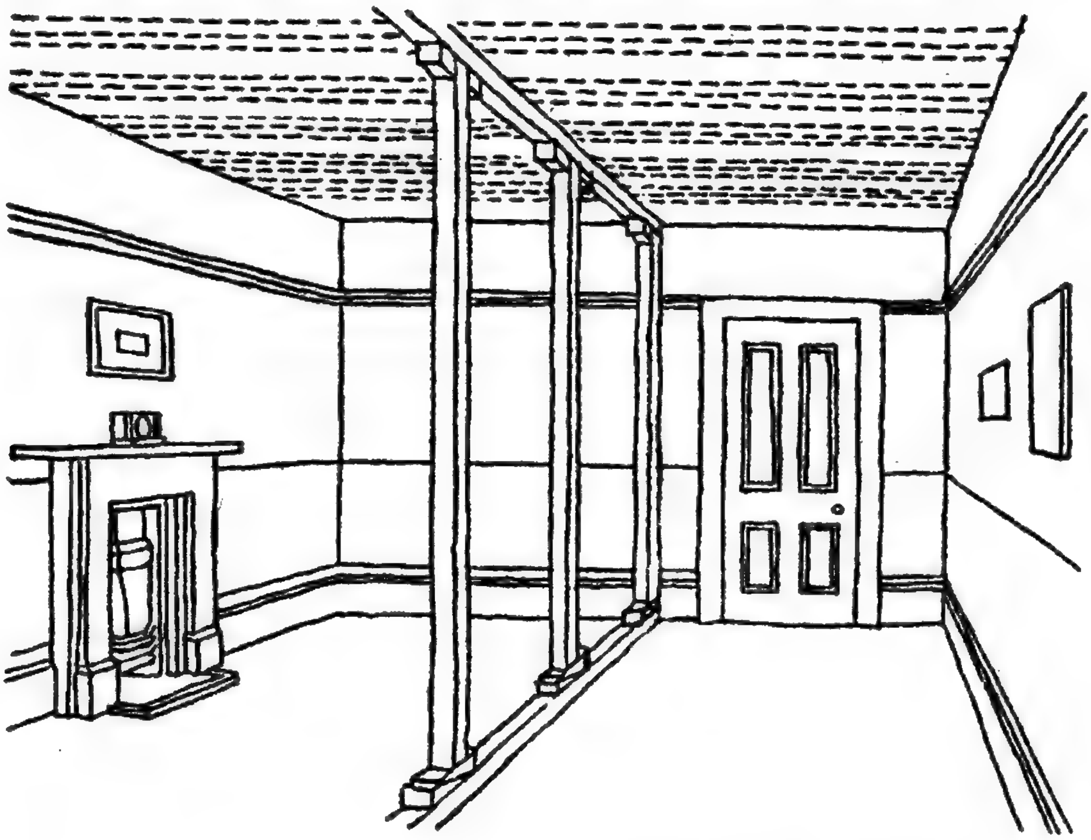
Alternatively, any room on any floor below the top floor may be used. Top floors and attics should be avoided as they usually do not give sufficient protection overhead from small incendiary bombs. These small bombs would probably penetrate the roof but be stopped by the top floor, though they might burn through to the floor below if not quickly dealt with.

In a house with only two floors and without a cellar, choose a room on the ground floor so that you have protection overhead

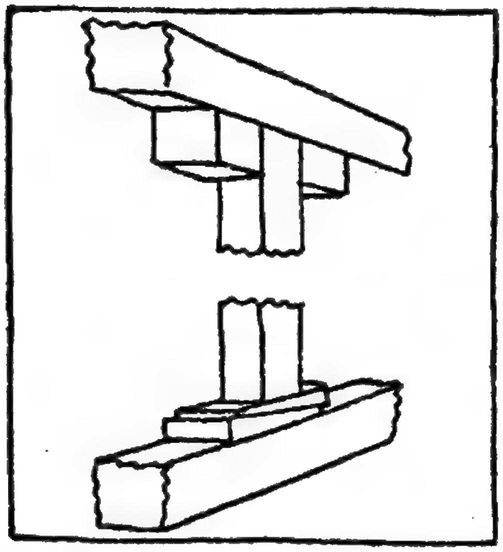
Strengthening the room

If your refuge-room is on the ground floor or in the basement, you can support the ceiling with wooden props as an additional protection. The illustration shows a way of doing this, but it would be best to take a builder's advice before setting to work. Stout posts or scaffold poles are placed upright, resting on a thick plank on the floor and supporting a stout piece of timber against the ceiling, at right angles to the ceiling joists, i.e. in the same direction as the floor boards above.

How to support a ceiling



The illustration below shows the detail of how to fix the props

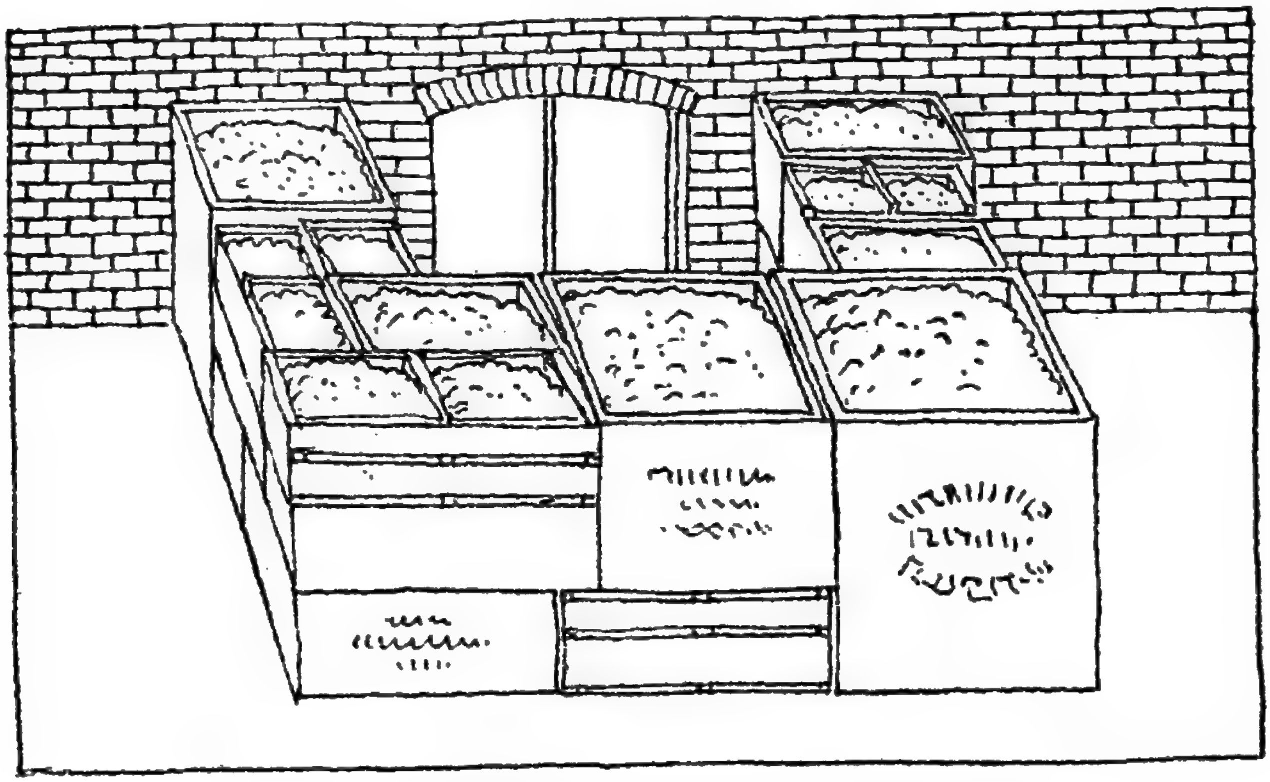


The smaller illustration shows how the posts are held in position at the top by two blocks of wood on the ceiling beam. The posts are forced tight by two wedges at the foot, driven in opposite ways. Do not drive these wedges too violently, otherwise you may lift the ceiling and damage it. If the floor of your refuge-room is solid, such as you might find in a basement, you will not need a plank across the whole floor, but only a piece of wood a foot or so long under each prop.

EXTRA PRECAUTIONS AGAINST EXPLOSIVE BOMBS

TRENCHES. Instead of having a refuge-room in your house, you can, if you have a garden, build a dug-out or a trench. A trench provides excellent protection against the effects of a bursting bomb, and is simple to construct. Full instructions will be given in another book which you will be able to buy. Your air raid wardens will also be able to advise.

SANDBAGS. Sandbags outside are the best protection if your walls are not thick enough to resist splinters. Do not rely on a wall keeping out splinters unless it is more than a foot thick. Sandbags are also the best protection for window openings. If you can completely close the window opening with a wall of sandbags you will prevent the glass being broken by the blast of an explosion, as well as keeping out splinters. But the window must still be sealed inside against gas.



A basement window protected by boxes of earth

Any bags or sacks, including paper sacks such as are used for cement, will do for sandbags. But if they are large, don't fill

Printed for the War Cabinet. May 1941.

MOST SECRET.

Copy No. 58

W.P. (G) (41) 44.

May 5, 1941.

TO BE KEPT UNDER LOCK AND KEY.

It is requested that special care may be taken to ensure the secrecy of this document.

WAR CABINET.

AIR RAIDS ON LONDON, SEPTEMBER–NOVEMBER 1940.

Memorandum by the Home Secretary and Minister of Home Security.

Framed buildings.

Most valuable information has been gained on the effects of bombs on framed buildings. Such buildings are practically immune to anything but a direct hit. Blast damage from bombs outside is usually confined to windows and internal partitions. Even parachute mines falling immediately outside the building or exploding on the roof produce negligible damage to structure or floors.

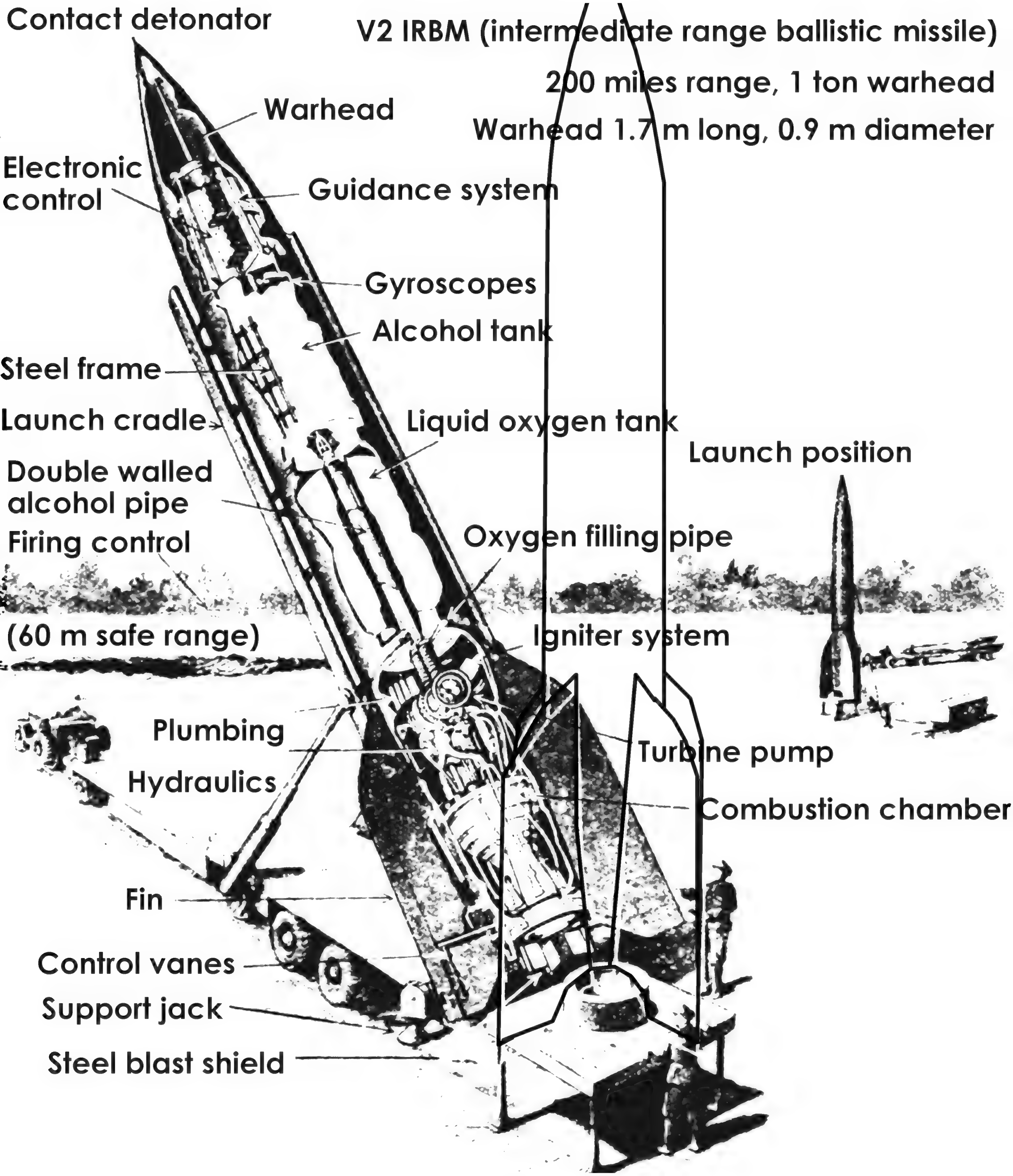
Relation of Casualties to Bombs Dropped.

From a knowledge of the number of bombs dropped and the casualties occurring in different boroughs, some idea can be gained of the effectiveness of bombs in producing casualties. The number of casualties per bomb varies widely from 1·59 in the least to 6·94 in the most populated boroughs, but it follows closely the apparent densities of population as shown in figure 1. The number of casualties per bomb is roughly a twelfth of the number of persons per acre, and the number of deaths per bomb about 1/60th of the number of persons per acre. From this it can be deduced that the mean distance at which injury from a bomb is likely to occur is 35 ft., and that at which the bomb is lethal is 15 ft.

The casualties per bomb in Central London fell steadily from an average of 3·7 in September to 2·7 in October and 1·7 in November. This corresponds to the considerable fall in population in most of the boroughs concerned.

Conclusion.

We may now say that we have a good general understanding, both qualitative and quantitative, of the effects of bombs on buildings and on cities. New types of bombs, particularly heavier bombs, may be used, but we can anticipate no startling change in the effects apart from increase in minor damage. With bombing of the present type the results of our work are to show that in urban areas, such as that of the County of London, *for one ton of bombs approximately* 10 *houses will be destroyed or will need pulling down.* 25 *more will be temporarily uninhabitable, and another* 80 *will be slightly damaged.* 80 *people will be made temporarily homeless and* 35 *will lose their homes permanently.* 25 *people, mostly among the latter category, will be wounded, the greater part of them slightly, and* 6 *will be killed or die from wounds.*


V2 IRBM (intermediate range ballistic missile)
200 miles range, 1 ton warhead
Warhead 1.7 m long, 0.9 m diameter
Contact detonator
Warhead
Electronic control
Guidance system
Gyroscopes
Alcohol tank
Steel frame
Launch cradle
Liquid oxygen tank
Launch position
Double walled alcohol pipe
Firing control
Oxygen filling pipe
(60 m safe range)
Igniter system
Plumbing
Turbine pump
Hydraulics
Combustion chamber
Fin
Control vanes
Support jack
Steel blast shield

Aldwych, 30 June 1944, V1 attack

V-2 ATTACK at Smithfield Market, London, where 110 people were killed and 123 seriously injured when pavements were crowded

CIVIL DEFENCE

RESCUE MANUAL

LONDON
HER MAJESTY'S STATIONERY OFFICE
1952

CHAPTER XI. USE OF HEAVY MECHANICAL PLANT IN RESCUE, DEMOLITION AND CLEARANCE OPERATIONS

In the last war it was found that at major incidents the use of heavy mechanical plant was frequently necessary in support of rescue operations. Such equipment was used to help in the quick removal of debris; to lift heavy blocks of brickwork or masonry; to take the weight of collapsed floors and girders so that voids could be explored and casualties extricated; to haul off twisted steelwork and other debris and to break up sections of reinforced concrete.

In future all these tasks may be required and heavy clearance may have to be effected to enable rescue and other Civil Defence vehicles

8 March 1945 Fig. 20 1 ton of TNT equivalent

Using heavy mechanical plant at the Smithfield Market V.2 incident.

to approach within measurable distance of their tasks. The problem of debris will in fact be a major factor in Civil Defence operations.

Heavy mechanical plant may be required for the following purposes :

(*a*) To assist in the removal of persons injured or trapped. At this stage mainly heavy plant is needed, particularly mobile cranes with sufficient length of boom or jib to reach for long distances over the wreckage of buildings.

(*b*) To force a passage for Civil Defence vehicles and fire appliances to enable them to reach areas where major rescue and other problems exist and require urgent operational action.

(*c*) To take certain safety measures—e.g., to pull down unsafe structures.

(*d*) To clear streets and pavements to help restore communications and to afford access for the repair of damaged mains and pipes beneath the streets.

(*e*) For the final clearance of debris and the tidying of sites. This is a long term and not an operational requirement.

Urgent Rescue Operations

During rescue operations in London in the last war the machines used with great success included heavy 3½-5 ton mobile cranes, mounted on road wheels, with a 30-40 ft. jib ; medium heavy 2-3½ ton mobile cranes, mounted on road wheels, with a 26 ft. jib ; heavy crawler tractor bulldozers ; medium crawler tractor bulldozers ; mechanical shovels and compressors, three stage, mounted on road wheels.

In the case of a large or multiple incident where access was obstructed by considerable quantities of scattered debris, a bulldozer or tractor was first employed in order to clear one or more approaches by which other equipment and personnel could reach the scene of operations.

Next, all debris of manhandling size was loaded into one-yard skips and discharged by the crane into lorries, giving increased manœuvring space to the Services operating on the site.

Heavy mobile cranes were then brought up to the incident where, used under the skilled direction of the rescue party Leader, they were invaluable for removing girders and large blocks of masonry which obstructed access to casualties or persons trapped. The necessary chains and wire ropes for these operations formed part of the standard equipment of the heavy and medium-heavy mobile cranes.

The work was, of course, carried out in close co-operation with the Rescue Parties who also used various forms of light mechanical equipment, such as jacks and ratchet lifting tackle for work in confined spaces.

Compressors sometimes proved valuable for breaking up large masonry such as fallen walls, into sections of a size and weight within the handling and lifting capacity of the cranes. This method was only used when it was known that there were no casualties under the masonry.

HOME OFFICE

SCOTTISH HOME DEPARTMENT

CIVIL DEFENCE HANDBOOK No. 7

Rescue

This Handbook is a revised edition of, and replaces, the Civil Defence Rescue Manual

LONDON

HER MAJESTY'S STATIONERY OFFICE

1960

CHAPTER 6

Types of Damage from Modern Air Attack

General Characteristics

6.1 When a nuclear weapon explodes an immense amount of energy is released almost instantaneously and the contents are transformed into a rapidly expanding white hot ball of gas at a temperature as high as that on the sun. From this "fireball" a pulse of intense light and heat is radiated in all directions. The materials in the fireball are also a source of radioactivity in various forms. As the fireball expands and cools, a powerful blast wave develops. As it cools still further, it shoots upwards to a height of many thousands of feet, billowing out at the top to give the appearance of a huge mushroom or cauliflower on its stalk.

6.2 The three forms of energy released in the explosion, namely, light and heat, radioactivity, and blast, all produce effects in different ways and in different proportions according to the position of the explosion in relation to the surface underneath. This chapter, however, deals primarily with the damage caused to buildings by the blast effect.

6.3 With nuclear weapons (as opposed to high explosive weapons), blast pressure rather than "impulse" tends to be the criterion of damage. If the effective blast pressure exceeds the static strength of the structure, failure must be expected. If it is less, no failure can occur however long the duration of the blast. In fact, nuclear bomb blast is more like a strong wind than the sudden blow of high explosive blast, and many of the failures observed at Hiroshima and Nagasaki and in subsequent tests resemble closely the kind of damage that might be done to buildings by a hurricane.

6.4 The scarcity of suction damage from the nominal bombs in Japan was due to the high blast pressures produced and to the fact that these were three or four times as great as the blast suction. With all such large explosions, if a building does not fail from blast pressure it is unlikely to fail under the lower stresses in the suction phase.

Effect of blast on structures

6.5 The type of damage which long duration blast (from nuclear weapons) causes to structures can possibly best be appreciated by considering the forces to which a simple building is subjected during the passage of a horizontal blast wave. When the blast "front" strikes the front wall it is reflected back, and the pressure in the wave front builds up to more than double the original pressure. However, this build-up only lasts for a very short time and is mainly important for large flat surfaces such as walls of big buildings.

Fig. 39 (a). Using a door as a stretcher

Fig. 39 (b). Using a door as a stretcher

CHAPTER 15

Principles of Levering and Jacking

15.1 The principles of levering and jacking are, in a variety of differing ways, brought into most aspects of rescue work. The purpose of lifting appliances is to gain power so as to lift a large load with a small force suitably applied.

Levers

15.2 The simplest appliance for gaining power is the lever, of which an improvised version made of laminated timber or an ordinary crowbar are most frequently used by rescue workers. There are two principal ways in which a lever can be used, as illustrated in the diagrams. In each case the advantage gained depends on the distance of (A), the centre of the load, and (C) the points where the push or force is applied from (B), the heel or fulcrum.

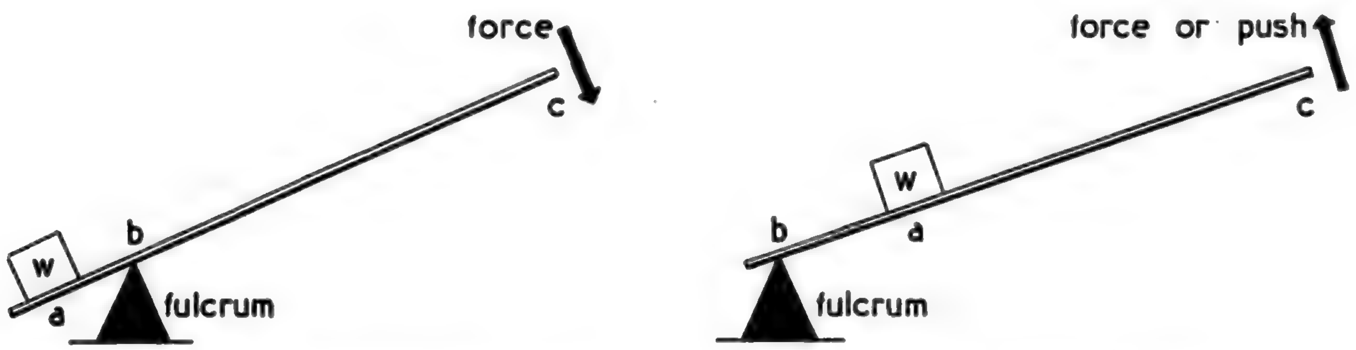


Fig. 68. Lever (downward force)   Lever (upward force)

15.3 The relation between the load and the amount of force required to lift it is in the same ratio as the length BC is to AB, where AB and BC are the distances of the weight and the force respectively from the fulcrum. A man using a 10-foot lever and bearing down at C with half his weight, say, 6 stone or 84 lb., against a fulcrum 1 foot from the other end of the lever, can lift a weight of $84 \times 9 = 756$ lb. because the length from fulcrum to hand is nine times the length from pivot to weight. If B is only 6 inches away from the weight the ratio is increased to 19 times its own weight.

Fulcrum blocks

15.4 A fulcrum block should be of wood (hardwood if possible), never of brick or other crushable material. It must be resting on a firm base, which should be as large as possible so as to distribute the weight to be lifted. The fulcrum must be placed as near to the weight as is possible under the circumstances, and it should never be placed at any point where there is a possibility of a casualty being buried immediately below.

In 12 months, 1940-1, the Blitz stray dog Rip (discovered by civil defence rescuers in Poplar, East London after an air raid) sniffed out 100 trapped casualties in London rubble.

Irma. Margaret Griffin used Irma and Psyche to find 233 trapped persons

STANFORD RESEARCH INSTITUTE

STANFORD, CALIFORNIA

June, 1953

Final Report

IMPACT OF AIR ATTACK IN WORLD WAR II: SELECTED DATA FOR CIVIL DEFENSE PLANNING

Evaluation of Source Materials

By

Robert O. Shreve

SRI Project 669

Prepared for
Federal Civil Defense Administration
Washington, D. C.

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Economics Research Division

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Table 1

Report Outline - USSBS Project

IMPACT OF AIR ATTACK IN WORLD WAR II:
SELECTED DATA FOR CIVIL DEFENSE PLANNING

Division I - PHYSICAL DAMAGE TO STRUCTURES, FACILITIES, AND PERSONS

Volume 1 Summary of Civil Defense Experience
Volume 2 Analytical Studies (Restricted)
Volume 3 Causes of Fire from Atomic Attack (Secret) --VITAL!!

The documents which should be given wide distribution for civil defense use are listed below, with a brief description:

a. USSBS Reports

Effects of the Atomic Bomb on Hiroshima, Japan (3 volumes).

Effects of the Atomic Bomb on Nagasaki, Japan (3 volumes).

These reports constitute two case studies of atomic bombing. Civil defense planners should be aware of the facts these documents record in great detail. Their distribution to all civil defense planners and analysts is highly desirable.

-9-

Effects on Labor in Clydebank of Clydeside Raids of March 1941, (REN 234) USSBS Target Int.(REN 236) Ministry of Home Security

A study of the effects on labor of bombing in a town of 50,000 people in which 76% of houses were rendered uninhabitable, 73% of the population homeless. An equivalent of 65 city days was utilized in the reconstruction.

-22-

Ministry of Home Security
Effects of German Air Force Raids on Coventry (REN 441)

The city, the attack, casualties, repairs and reconstruction (cost), absenteeism, population movements, and housing occupancy. Six pages and charts and graphs. Twenty percent of houses rendered uninhabitable or destroyed, a total reconstruction cost of £ 3,492,000. Average time lost by worker after November raid was eleven days; average after April raid was 7 days. Nine percent of the workers evacuated to points within reach of the city.

Number and Classification of Official Evacuees in Great Britain in 1939 and 1940

900,000 of the 1.5 million returned to the target areas after four months of war.	September, 1939		January, 1940	
	Number	Percentage Distribution	Number	Per cent of Those in September, 1939
1. Unaccompanied school children	826,959	56.1	457,600	55
2. Mothers and accompanied children	523,670	35.5	64,900	12
3. Expectant mothers	12,705	0.9	1,140	9
4. Blind persons, cripples, and other special classes	7,057	0.5	2,440	35
5. Teachers and helpers	103,000	7.0	46,500	45
Total	1,473,391	100.0	572,580	39

Source: R. M. Titmuss, *Problems of Social Policy* (London: H.M. Stationery Office, 1950), pp. 103 and 172.

Effectiveness of Some Civil Defense Actions in Protecting Urban Populations (u)

Appendix B of
Defense of the US
against Attack by Aircraft and Missiles (u)

ORO-R-17, Appendix B

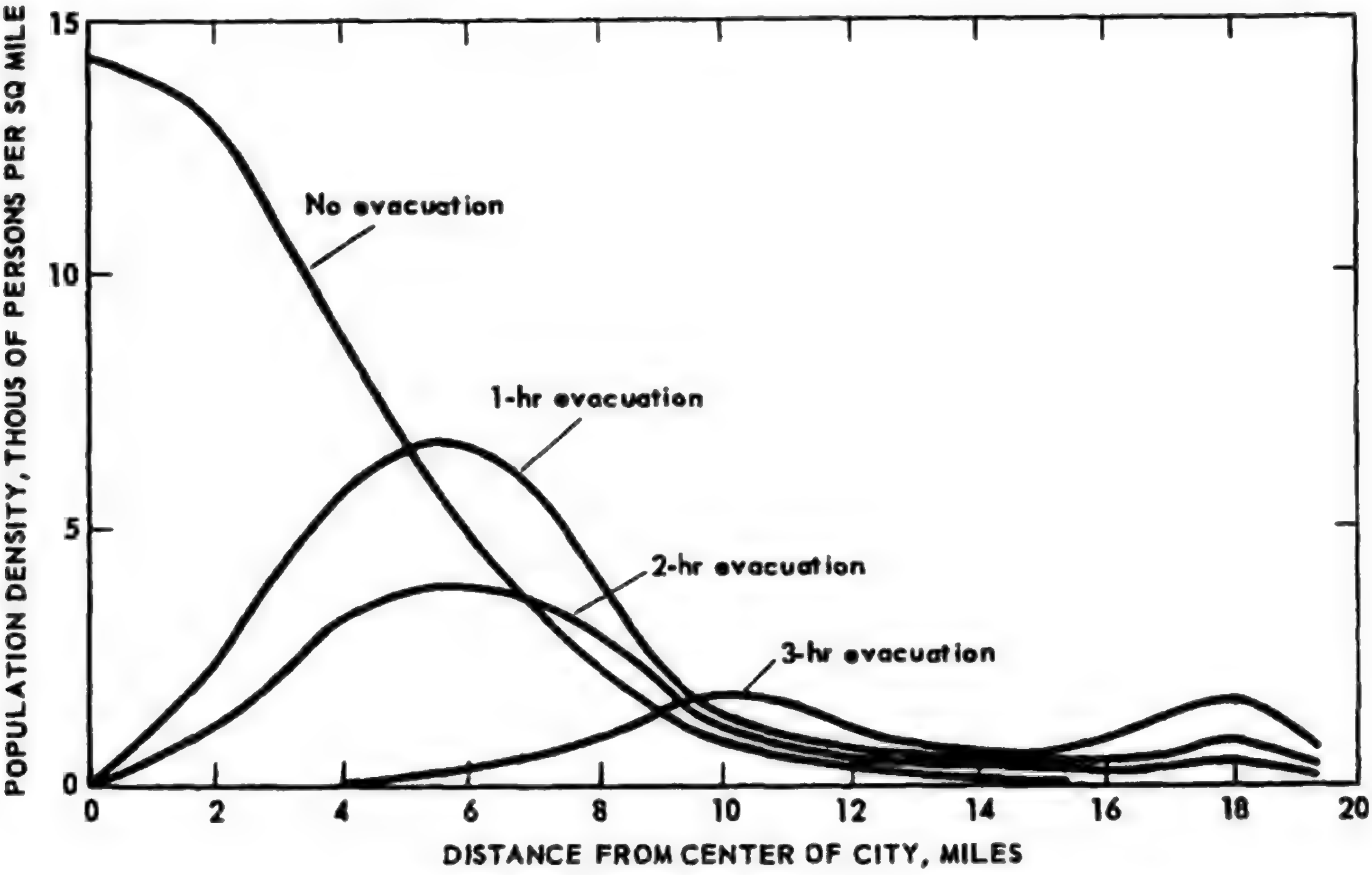

Fig. 10 — Population Density of Washington Target as Function of Distance from Center of City for Three Evacuation Times

In Britain, by early 1940, the government had issued free, to families of low income, some 2.3 million bomb shelters, enough to shelter over one-fourth of the population. But by the same time -- after Munich had brought home to the British people the peril in which they stood, even after the war had begun -- less than 1000 shelters had been *purchased*. This was under 0.04 per cent of the total number in place, despite the fact that the shelters were sold at cost.[7]

For protection against chemical and biological attack, our National Plan proposes that protective (gas) masks be made "...available to the people through regulated commercial distribution...."[8] or in a word, sold. That too is nonsense. In Britain, in contrast, the government had decided by 1935 that it would be futile to expect the population to buy their own masks. During the Munich crisis, 38 million gas masks were issued free to the people of Great Britain.[9] The British government of that time could scarcely be called war-minded or over-prepared for war. Still less, it appears, are we prepared in 1961.

7. O'Brien, Terence H., *Civil Defence,* London, HMSO, 1955 at 335. In 1939 the government had decided to issue Anderson (corrugated steel) shelters free to householders with incomes of not over £ 250 a year. *Id.*, 188.

8. OCDM National Plan, Annex 24, "National Biological and Chemical Warfare Defense Plan," at 6.

9. O'Brien, *op. cit. supra* note 7 at 165.

-- The Argument That Increased Spending for Nonmilitary and Other Defenses May Cause an Economic Decline

A celebrated statesman not many years ago elegantly put (or rather, asserted) the argument for "national bankruptcy":

CHAMBERLAIN IN LATE 1936 WHEN CHANCELLOR OF THE EXCHEQUER

> If we were now to follow [X's] advice and sacrifice our commerce to the manufacture of arms, we should inflict a certain injury on our trade from which it would take generations to recover, we should destroy the confidence which now happily exists, and we should destroy the revenue.... [33]

And, a comment on that argument,

> It was held very strongly that financial stability was our fourth, and final, military arm, that we must balance [the national budget], and avoid interference... with trade.... [34]

The statement quoted was not made in 1949, when not muscle but fat was being pared from our military budgets. It was not made in 1955 or 1960. It was made, rather, in the 1930's. The statesman who so anxiously viewed the dangers to be apprehended from increased expenditure for arms was Neville Chamberlain. "X" was Winston Churchill. Britain was, if not "generations," at any rate half a generation in paying the bill for Chamberlain's economics. Only recently have her trade, revenue and financial stability recovered from the economies of Stanley Baldwin and Neville Chamberlain.

33. Feiling, Keith, The Life of Neville Chamberlain, London, Macmillan, 1946 at 314. Quotation reproduced by kind permission of the author, MacMillan & Company Ltd. and St. Martin's Press, Inc.

34. Id. at 316.

--The Question of Public Apathy--British Experience Before World War II Compared

The view is often expressed that the population is apathetic, or even hostile, towards nonmilitary defense, and that nothing can be done to develop these defenses until public apathy changes to concern. This view was succinctly put by a member of the House committee which passes on budget requests for OCDM. He said in March, 1959, that, "The Congress is not going to shove something down the throats of the people that they are not interested in. If you did, the Members of Congress would not be here very long."[46]

13

A nation-wide opinion survey by the Institute for Social Research of the University of Michigan, made in 1957, revealed, among other things, that 68 per cent of the population favored planning to evacuate cities, and that 90 per cent favored constructing shelters for people who lived in areas that might be attacked.[47]

Whatever the present reaction of the public might be to a program for nonmilitary defense, it is nearly certain that after a frightening crisis had occurred, the public would not only demand these programs, but would be highly critical of a government which had not taken the necessary action. This, at least, was the experience in Britain.

Munich, however, changed all that. War seemed so imminent that the government ordered day and night digging on trenches in parks and open areas. It issued gas masks to some 38 million citizens.[50] Then, when fitting gas masks and digging trenches had given the citizens personal proof of the threat which hung over them, "Fatalism about providing effective protection against air attack was... replaced by a feeling that this could be done, if the authorities showed enough will and energy."[51]

14

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46. U.S. House, Committee on Appropriations, Hearings, Independent Offices Appropriations, 1960, 86th Cong., 1st Sess. (1959) at 486.

47. Pohlenz, D. Dean, "Problems of Civil Defense Preparedness -- A Policy for Today," Washington, Industrial College of the Armed Forces Student Exercise M57-83 (1957) at 33.

49. O'Brien, Terence H., History of the Second World War: Civil Defence, London, HMSO, 1954 at 93, 99 and 104.

50. Id. at 161 and 165.

51. Id. at 166.

Bertrand Russell, for example, wrote in 1959 that,

> On the most favourable hypothesis, [the postwar world] would consist of destitute populations, maddened by hunger, debilitated by disease... incapable of supporting educational institutions, and rapidly sinking to the level of ignorant savages. This, I repeat, is the most optimistic forecast which is in any degree plausible.[61] [Emphasis added.]

This notion of the extinction of civilization, or even of all life, is a comforting one.[63] Most important, it ensures that a nuclear war will never be fought, since no sane (or perhaps even moderately insane) national leader would consider thermonuclear war as an instrument of policy. Also, if there is really nothing that can be done to mitigate the effects of nuclear war, rational men need not trouble themselves about the problems of preparing nonmilitary defenses -- or of paying for them.

The theory that thermonuclear war automatically results in world annihilation has had, and still has, some highly respectable adherents. In 1955, for example, fifty-two Nobel laureates subscribed to the statement that unless all nations renounced the use of force, they would simply "... cease to exist."[64] Writers on disarmament in 1961 continue to point out that it would be impossible to "... protect [civilians not killed by the initial attack on cities] against fallout and starvation,"[65] and that "Proponents of the arms race are willing to risk the destruction of civilized society...."[66]

--The View That National Security Can Best Be Achieved by Buying Only Offensive and Active Defensive Weapons

61. Russell, Bertrand, Common Sense and Nuclear Warfare, London, copyright (C) 1959 by George Allen and Unwin, Ltd., quotation reproduced by kind permission of Simon and Schuster, Inc. The notion of mutual extermination is also alluded to at 32, and the survivors are characterized as starving and debilitated at 26.
62. On Thermonuclear War, 35.
63. Id. at 11.
64. Id. at 9. Compare Bertrand Russell's views, supra note 61.
65. Sohn, Louis B., "Security Through Disarmament," 192 The Nation 159-163 at 159 (February 25, 1961).
66. Melman, Seymour, "The 'Arms-Control' Doctrine," 192 The Nation 114-116 at 116 (February 11, 1961).

Clark, Grenville and Louis B. Sohn, World Peace Through World Law (2d ed.), Cambridge, Massachusetts, Harvard University Press, 1960.

-- The Argument That Nonmilitary Defense Would Destabilize the Balance of Terror

To take any steps to protect the population would be to do them a disservice, since it might make war "thinkable" again. And whatever steps were taken, millions or tens of millions would be sure to die.

A variant of the hostage theory is that if we were to embark on a serious program for nonmilitary defense, we should inescapably spread war-mindedness among the American people.[71] Once they were awakened to the possibility, or worse the "thinkability," of war, they would inevitably become more hostile towards the source of the danger, namely, the USSR. They might then be expected, with the American penchant for grasping nettles (those, at any rate, recognized as nettles), to press for a first strike against the Soviet Union.

But other countries, not least the Soviet Union, do have nonmilitary defense programs of substantial value.

It is not, in any case, self-evident that a nonmilitary defense program would have a destabilizing (or unbalancing) effect upon American psychology. If anything, a program which included, for example, building fallout shelters or issuing radiation meters, might, by bringing home the threat of war to the American people in a highly personal way, incline them rather to a sober and pacific than to a war-like psychology. City dwellers might reflect upon the fact that their shelters, at least under any program the United States is likely to undertake in the next five years, would give them not a certainty but only a fair to good chance of survival. Rural residents might reflect upon the prospect of an incursion of refugees from the cities.

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71. Letter from Dean David F. Cavers, Harvard Law School, New York Times, March 20, 1960, page 10E, column 6. See too Brown, Harrison and James Real, Community of Fear, Santa Barbara, California, Center for the Study of Democratic Institutions, 1960.

This whole problem of psychological response to nonmilitary defense clearly requires detailed study by experts. British experience in the Munich and post-Munich period may not be without relevance.[73]

--Would A Nonmilitary Defense Program Injure Prospects for Arms Control?

Finally, there is the question whether a program for nonmilitary defense is compatible with plans for arms control or even disarmament.

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the reverse, it should not hazard the success of any arms control or disarmament negotiations in which the Soviets are seriously interested, and it would stabilize any arms control agreement that might be concluded.

73. See, for example, O'Brien, op. cit. supra note 49 at 329 on response to the anti-gas program, and Titmuss, Richard M., Problems of Social Policy, London, HMSO, 1950 at 29-39 on response to evacuation plans and programs.

Thermonuclear war is a grisly topic. It is, however, one about which we would do well to think. The argument might be made that research on war may make it somewhat more likely to occur. It is more probable, however, that the reverse is true, that not thinking about thermonuclear war may make it easier to blunder into one -- or what might be even worse, to lose one.

It would be well indeed if nuclear war would be unmistakably so annihilating as to be unthinkable, at least for sane men, as Bertrand Russell and others hold. But it would be unfortunate if this view prevailed only in the West and not in Moscow and Peiping. There is good evidence that it does not, especially in the latter. There is in any case something of schizophrenia about spending tens of billions each year on thermonuclear weapons and their delivery vehicles and then refusing to think about the ways and conditions in which they might be used, or (more hopefully) the ways in which we can best assure, short of surrender, that they will not be used.

The best study to date is Herman Kahn's On Thermonuclear War, published late in 1960.[77] Most of what follows in this chapter draws heavily upon Kahn's work, though it is impossible to do it justice in so

small a space. He analyzes, so far as possible in a quantitative way, the probable or possible causes, courses and effects of thermonuclear wars which might occur in the next decade. Kahn's work has been bitterly attacked, although to date in no very temperate or reasoned fashion. It has been called "a moral tract on mass murder," "permeated with a bloodthirsty irrationality," and its quantitative approach a "Higher Incoherence."[78] It has been said to show "narrowness of vision," and to have about it an "air of unreality."[79] But coherent criticism, reasoned rather than stated, marked by broadness of vision or an air of reality, has yet to appear, certainly in more than fragmentary form.[80]

77. Kahn, Herman, On Thermonuclear War, Princeton, N.J., Princeton University Press, 1960. On U.S. national strategy see too Rowen, op. cit. supra note 36, and Washington Center of Foreign Policy Research, Johns Hopkins University, Study for Senate Committee on Foreign Relations, Developments in Military Technology and Their Impact on United States Strategy and Foreign Policy, 85th Cong., 1st Sess. (Comm. Print 1959).

78. Newman, James R., "A Moral Tract on Mass Murder," The Washington Post, February 26, 1961, page E7, columns 5-8. The level of coherence of Mr. Newman's critique is best left unstated.

79. Wolff, Robert Paul, "The Game of War," 144 The New Republic (February 20, 1961) 9-13.

80. The usual criticism of Kahn's work is that it does not sufficiently take into account political problems. Careful, or even casual, reading of On Thermonuclear War, however, shows that Kahn has a better grasp of political problems than most of his political-scientist critics have of strategy.

We may expect Soviet or Chinese support for "progressive, revolutionary national liberation wars"[83] in such areas as Algeria or the Congo. We may see guerilla action in Southeast Asia or other areas on the periphery of the "Socialist camp." We may even see limited wars, fought without or perhaps even with tactical nuclear weapons. Soviet missiles may be rattled again, as they have been rattled on behalf of Nasser and Castro. (American missiles might also be rattled, though this seems unlikely during the next few years, at least.) Finally, even negotiations for arms control or disarmament may be devices of cold war conflict, as they have too largely been to date.

What Are We Trying to Deter?

Kahn points out that it is critically important to distinguish between deterring an attack upon the United States and attacks or major provocations at other points, for example, a "squeeze" or even armed attack on Berlin. The same weapons, dispositions of weapons, and strategies do not suffice for both ends.

22

83. **This was promised in the manifesto issued by the leaders of 81 Communist parties after their meeting in Moscow in late 1960. New York Times, December 7, 1960, pages 14 to 17, with the "progressive revolutionary significance" of "national-liberation wars" noted at page 17, column 7. Premier Khrushchev also adverted to the inevitability of "national liberation wars" in a report delivered January 6, 1961. New York Times, January 19, 1961, page 6, column 4.**

84. **Berlin was noted as a "seat of international provocation" in the late-1960 manifesto. New York Times, December 7, 1960, page 15, column 2. (Any Western posture other than abject surrender is doubtless "provocative" in the communist lexicon.)**

As Kahn has put it, history has a disconcerting way of being "...richer and more imaginative than any scholar."[86]

86. **On Thermonuclear War at 557.**

23

It is a fearsome thing to contemplate the risk of 10 or 20 or 120 million Americans, or Americans and Britons, being killed in a war, for example, over two and one-half million West Berliners.

24

--Devices to Tide Us Over the Earlier 1960's

The Soviets might not, of course, decide to risk everything, or at any rate a great deal of capital and some millions of their citizens, on our succumbing to postattack coercion. If the Marxist-Leninist dialectic condemns spurning the opportunities offered by history, it also condemns taking excessive risks, a sin termed "adventurism."[109] What can we do to increase the risks to be apprehended from an attack on the United States?

30

109. See, for example, Garthoff, Raymond, Soviet Strategy in the Nuclear Age, New York, Praeger, 1958 at 5.

--A $100 Billion Program Including Blast Shelters and Extensive Preparation for Economic Recuperation

The "splendid," $100 billion or more, program is the one which might raise some reasonable Soviet apprehension that we might strike first. This program, including blast shelters into which the urban population could "duck" in a matter of twenty or thirty minutes, would in fact be part of a credible strategic posture allowing us to make a first strike.

(Expensive deep shelters create "Maginot Line" delusions: Hitler simply adapted plans to go around obstructions. Similarly, shelters in Hiroshima were unoccupied due to surprise attack! If you have deep shelters, an enemy will plan surprise attack. It takes 20 min to get into shelters, but only 3 minutes for SLBM submarine missile attack from offshore!)

45

--History and Arms Control

The lessons of history, for what they may be worth, include those of 1914, when Europe stumbled into a major war which no power wanted, as a result of a minor war about which only Austria or Serbia were really serious. As Herman Kahn has pointed out, there are disturbing analogies between the years before 1914 and those in which we now live.[158]

(Wrong: the German Kaiser did WANT war and had been planning since 1912 to use any excuse for starting war, implementing Schlieffen's plan!)

--Arms Control for the 1960's

At all events, it is clear that the problems of arms control must have more intelligent, more intensive, and more sustained attention than they have yet had, if we are to avoid repeating something like the disasters of either 1914 or 1933-1939. Views on the approaches required, as noted above, vary widely.

47

158. Kahn, On Thermonuclear War 368-370.

It would plainly be futile, in view of the vigorous Soviet pacification of Hungary, or of the Chinese liberation of Tibet, to rely upon "world opinion " (whatever that is) to deter violations. . . .

One sanction might be the prospect of a renewed arms race, triggered by the discovery of violations. But this might not deter cheating, particularly if the party bent on violation believed it could secure a commanding position before the injured party could catch up. (Here we might remember the belated but futile efforts of the British to regain air parity, after Hitler's rapid expansion of the Luftwaffe.)[176]

50

176. See, for the history of that dismal episode in the history of the West, Sir Winston Churchill's The Gathering Storm, chapter 7. Kahn points out that if one side obtained a significant lead because of evasion or rapid rearmament after the agreement broke down, it might then "...feel compelled to perform a great public service by arranging to stop the arms race before a dangerous balance of terror was restored. It could do this most reliably by stopping the cause of the arms race -- its opponent. Most writers ignore this situation...." On Thermonuclear War at 230.

Is Nonmilitary Defense Possible?

If nonmilitary defense is necessary, is it possible? In the discussion to this point, it has been assumed that it is. But can one say, with any measure of confidence, that nonmilitary defenses could in fact ensure the survival of most or all of the population? Even if a shelter program could preserve the lives of most Americans against fallout or even blast, would they emerge into a world worth living in, or indeed, possible to live in? What of the genetic effects of war? Would all children be born deformed? What of leukemia, of cancer, or of a shortened span of life? What of strontium-90? What of the standard of living? Would the survivors, and their descendants, be reduced to grubbing out a wretched existence, with our economy shattered beyond hope of repair? What of the social impact of attack? Could we expect that the survivors, as Bertrand Russell has predicted, would "rapidly sink to the level of ignorant savages"?

Further, nonmilitary defense must be designed to cope with widely varying conditions. The nature of the postattack environment would depend upon the weight and pattern of the enemy's attack--which might in turn be influenced by the nonmilitary defense measures we had taken. The areas contaminated by fallout would of course be determined by the winds prevailing on the day of attack, as well as by the enemy's attack pattern. Antiaircraft and antimissile defenses would also affect the nature of the postattack environment.

The major systems analyses of nonmilitary defense so far published are the Rand Report and a more detailed work done by Mr. John Devaney's OCDM Operations Research Office, A Preliminary Analysis of Non-Military

Defense.[186] Both of these studies give some ground for sober confidence that the United States could survive thermonuclear wars in the 1960's and even beyond, given appropriate levels of nonmilitary defense preparation. But much more detailed research remains to be done. There are still major areas of uncertainty in the performance of nonmilitary defense systems. The principal policy suggestion of the Rand study was therefore that the United States undertake a broad program of research and development on nonmilitary defense problems, to cost some $200 million over two or three years.[187]

186. OCDM, A Preliminary Analysis of Non-Military Defense, Battle Creek, Michigan, 1959.

187. Kahn, Herman, et al., R-322-RC 184 at 44. (This is about fifty times the present OCDM annual research appropriation.)
R-322-RC Rand Corporation Report on a Study of Non-Military Defense

--Long-Term Effects of Fallout--Genetic Effects and Life-Shortening, and the Strontium-90 Problem

Even if fallout at first decays rapidly, so that fallout shelters could protect most of the population from immediate death or illness due to radiation, would the longer-term effects of radiation make life as we know it either impossible or insupportable for the survivors? Despite the rapid initial decay of fallout, a relatively small amount of contamination would remain in the environment for a long time. This would include strontium-90, a long-lived isotope produced by nuclear fission.

The Rand Report states that about four per cent of babies are at present stillborn or die shortly after birth, two per cent are malformed and two per cent develop later troubles attributable to genetic defects.[200] If as the result of nuclear war, both parents had been exposed to about 250 roentgens, spread over a long period, their chances of producing a seriously defective living child might increase from four per cent to five per cent.[201]

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199. Testimony of Dr. James F. Crow, Professor of Genetics, University of Wisconsin, in 1957 fallout hearings, op. cit. supra note 193 at 1013. More recent experiments show that there is a possibility that radiation received over an extended period may not have as much genetic effect as radiation received over a short period. U.S. Congress, Joint Committee on Atomic Energy, Hearings, Fallout from Nuclear Weapons Tests, 86th Cong., 1st Sess. (1959) at 1566.

200. Kahn, et al., op. cit. supra note 184 at 16.

201. Kahn, On Thermonuclear War at 46.

Strontium-90, produced by fission, falls out over crop and pasture lands, is taken up by plants, and can eventually find its way into human bones, where it may cause bone cancer or, in smaller amounts, cause bone lesions and interfere with bone growth, particularly in children.[204]

204. See generally Kahn, On Thermonuclear War at 63-72.

All of these long-term effects of nuclear war are serious, particularly the strontium-90 problem. It appears, however, that with proper preparation, it should be possible to alleviate them. In chapter 2 the subject of decontamination, or removal of radioactive debris, is discussed. In chapter 3 is discussed a scheme suggested by Herman Kahn to ensure that relatively contaminated food be consumed only by older persons, whom it will not much affect, with the least contaminated food reserved for children and pregnant women.

The Rand Report concludes that "...long-term radiation problems are a less critical threat to the survival of a population than the central short-term problem, namely, how to protect a substantial fraction of the population from the immediate disaster of a nuclear war."[205]

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205. Kahn, et al.,

R-322-RC Rand Corporation Report on a Study of Non-Military Defense at 21.

Even if the medical effects of nuclear war might not be insoluble, there remains the problem of economic recovery. Would the survivors be condemned to lives without hope, with standards of living, for most, similar to those of the early years of the industrial revolution?

In the absence of reliable predictions of social response to thermonuclear attack, there is a tendency to lurid speculation. One can too easily visualize society collapsing, with the survivors organizing themselves into robber bands and struggling for the few economic resources remaining, or masses of city dwellers suffering crippling mental breakdown, or mankind rejecting science and technology and reverting to a hunting-and-gathering or at best pastoral existence. Others speculate upon the probability of mass panic or of widespread looting and other criminal behavior.

Just such speculations were made in Britain before the war, and made by sober scientists, government officials and soldiers. The Army Council instructed General Officers Commanding that "the initial preoccupation" of the troops would be "to sustain public morale."[214] At the time of Munich, when evacuation was being considered, "...discussions were held on the question of drafting regular troops into London to keep order and prevent panic...."[215] Gloomiest of all were the predictions of the psychiatrists, who thought that mental casualties might outnumber physical casualties by two or three to one:[216]

> ...the experts foretold a mass outbreak of hysterical neurosis among the civilian population. It was expected that the conditions of life brought about by air raids would place an immediate and overwhelming strain upon the individual. Under this strain, many people would regress to an earlier level of needs and desires. They would behave like frightened and unsatisfied children, and they would demand with the all-or-none vehemence of infants the security, food and warmth which the mother had given in the past.

None of this, of course, occurred. Rather than a dramatic increase in neurosis or mental illness, there was in fact a decrease. Statistics for insanity, suicide, drunkenness and disorderly behavior fell by as much as half.[217] Workers absented themselves from their factories after heavy bombing only when their houses had been damaged or destroyed, and then only for an average of six days.[218]

214. Titmuss, op. cit. supra note 73 at 19.

215. Id. at 30.

216. Id. at 338-339.

217. Id. at 340-341.

218. Id. at 341.

Individual and group protection against chemical attack poses great problems. In World War I, gas was considered one of the most effective means for producing casualties,[117] even though the CW agents used then were far less lethal than the nerve gases developed in Germany prior to World War II. A seven-ton load of nerve gas can reportedly cause casualties over an area fifteen miles wide and twenty-five to fifty miles long, and death over an area of 100 square miles,[119] given weather conditions favorable to the spread of gas clouds.[120] New non-lethal gases are under development, including the so-called psychochemicals, related to compounds used to simulate mental disease, and other incapacitating agents. These agents affect victims by upsetting normal behavior patterns or physiological processes,[121] though their short-term effectiveness appears to suit them more to tactical use against troops than to attack of civilian populations.

117. Rothschild, Brig. Gen. J. "Germs and Gas, the Weapons Nobody Dares Talk About" 218 Harper's Magazine 29 at 30 (June 1959). This article also states, ibid, that 26.8 per cent of AEF casualties were caused by gas. FCDA Technical Bulletin 11-25, "Introduction to Chemical Warfare" (1957) states that mustard gas and other blister gases produced more than 400,000 casualties in the last 16 months of World War I, more than were caused by any other weapon then in use. U.S. House, Committee on Science and Astronautics, Research in CBR, House Report No. 815, 86th Cong., 1st Sess. (1959) states at 4 that some 9 million artillery shells filled with mustard gas produced about 400,000 casualties, which effect was about five times that produced by high explosive shell, on a casualty per ton of shell basis. One should also note that CW casualties in World War I included few deaths. About one-third of U.S. casualties were caused by gas, but only 2 per cent of these died, as compared with 25 percent of nongas casualties. Ibid.

119 U.S. Senate, Committee on Armed Services, Hearings, Civil Defense Program, 84th Cong., 1st Sess. (1955) Part 2 at 800. The 100 square mile figure also appears in ACS, id. at 3.

120. "Inversion" conditions, where air temperatures increase with increase in altitude, are most favorable to the spread of gas clouds, and obtain on clear nights and early mornings until about one hour after sunrise. U.S. Department of the Army, Technical Manual 3-240, Field Behavior of Chemical Agents, Washington, 1951, at 16.

121. U.S. House, Committee on Appropriations, Hearings, Department of Defense Appropriations for 1960, 86th Cong., 1st Sess. (1959) Part 6 at 364-365 and 426-436.

In Great Britain, in contrast, some 44 million masks were distributed by the outbreak of World War II, virtually one per inhabitant, and 1.4 million infants' respirators and 2 million children's masks by January, 1940;[137] 55 million masks are now stockpiled in Britain for issue to civilians.[138] **(They are 1950 designed civilian C7 respirators.)**

Procuring 100 million masks for that part of our population concentrated in urban areas might cost $250 million, at $2.50 per mask, and extensive training in defense against BW and CW would also be required.

137. O'Brien, Terence, Civil Defence, London, HMSO, 1955 at 330. Note that as early as 1935 the British government decided that masks would have to be issued free of charge. Id. at 61.

138. Interview Col. Francis B. Stewart, FCDA (now OCDM), Battle Creek, Michigan, January 30, 1958.

3000 roentgens per hour intensity at one hour
12,000 roentgens outdoor dose in the first year

10,000 r in the first two weeks (emergency phase)
2000 r in the remaining fifty weeks (reclamation phase)

EMERGENCY PHASE (10,000 r)		RECLAMATION PHASE (2000 r)	
Shelter attenuation	10,000 r dose reduced to	Decontamination effectiveness (reduction to)	2000 r dose reduced to
1/100	100	90% (1/10)	200
1/1000	10	99% (1/100)	20

Radiological decontamination involves no very mysterious or sophisticated techniques. In general, fallout material can be swept or flushed off

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Evacuation

Contrary to popular belief, the effectiveness of tactical evacuation is by no means destroyed by the ICBM. While it is clear that no tactical evacuation could even be started during the 30-minute flight of an ICBM, it is also true, as the Rand Report points out, that cities are not likely to be attacked with the enemy's first ICBM salvo, and it is quite possible that most cities might not be attacked at all.

As Herman Kahn has pointed out, a national evacuation capability could be of the greatest importance in time of international crisis: If the Soviets evacuated their cities, they would have made it highly credible that they were prepared to go to war unless we backed down.[155]

155. Kahn, Herman, On Thermonuclear War, Princeton, N.J., Princeton University Press, 1960 at 213-214, also 132. Objections to evacuation and other nonmilitary defense measures are dealt with at 641-651, with objections bearing on evacuation in particular at 648-651.

The Bureau of Roads in 1956 prepared a report[160] on national evacuation capabilities for 161 urban target areas, containing 90.7 million people, about 55 per cent of the population. The report assumed orderly and disciplined movement, making maximum use of escape routes, and the findings included the following:[161]

(1) In 1 1/2 hours, 32 million persons could be evacuated at least 15 miles from the centers of target areas, over existing highways and streets;

(2) In 4 1/2 hours, 72 million persons could be evacuated at least 15 miles from target area centers;

(3) In 2 hours, 22 million persons could be evacuated at least 25 miles;

(4) In 5 hours, 53 million persons could be evacuated at least 25 miles;

(5) Evacuation of the largest cities within reasonable time limits would not be possible.

In sum, four hours' warning would allow substantial clearance of all but the largest cities, and even in these cities, this warning would allow evacuation of some 9 million of their 48 million inhabitants.[162]

160. Reprinted and discussed in U.S. House, Committee on Government Operations, Hearings, New Civil Defense Legislation, 85th Cong., 1st Sess. (1957) at 111-136.

161. Discussed id. at 124-126.

162. OCDM Operations Research Office, A Preliminary Analysis of Nonmilitary Defense, Battle Creek, Michigan, 1959 at 169.

Since 1956 Great Britain has had a simple scheme for classifying radiation zones by intensity and for evacuating the most dangerous zone, of 1000 r/hr and upwards at H + 1.[171] Such a program is dependent on a monitoring system, so that fallout zones may be delineated and appropriate instructions given their inhabitants. It requires sophisticated and technically competent control, related to the area affected by fallout, not to preattack political subdivisions.

Remedial evacuation also requires detailed arrangements for traffic control, if existing transport within the most dangerous area is relied on for evacuation.

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171. Home Office, Radioactive Fall-out, Provisional Scheme of Public Control, London, HMSO, 1956.

The requirement for rescue forces would depend upon the number of survivors trapped or incapacitated in areas which could be approached by rescue teams. OCDM estimated that in the 1446-megaton attack assumed for the 1959 JCAE hearings, 11.5 million people would have been fatally injured by blast and heat effects and 6.3 million nonfatally injured. Fallout would have caused a further 10.7 million fatal and 10.9 million nonfatal injuries.[175] Many of the blast casualties would require to be rescued and, together with fallout casualties, to be transported from the danger area. Other casualty estimates, however, show markedly fewer blast injuries, on the order of one-fourth of those estimated in the JCAE hearings.[176]

(JCAE hearings used gross Hiroshima casualty data, which applies to people watching the B-29 deliver bomb, i.e. no proper "duck and cover" for elayed blast behind windows.)

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175. 1959 JCAE Hearings, Effects of Nuclear War, at 651.

176. SRI calculations show only 1.6 million blast casualties from a 1500-megaton attack

177. Note that casualty effects are extrapolated from experience at Hiroshima and Nagasaki, which were attacks with air-bursted kiloton weapons. U. S. Atomic Energy Commission, Effects of Nuclear Weapons, Washington, 1957, at 456. Factors which may affect casualty numbers include yield, height of burst, strength of buildings (or shelters,) and the weather at the time of attack. Ibid. It is interesting to note that prewar British estimates of casualties from aerial attack, based on limited experience from World War I, turned out in the event to have been too high by 6 times.

Finally, fallout would limit rescue operations. Fallout from surface bursts far upwind might make operations impossible, if radiation levels were so high that rescue crews could not work without accumulating harmful radiation doses. Even if rescue groups could approach damaged areas from upwind, rescue of severe blast and burn casualties from within six or nine miles of ground zero would not be possible to a significant extent, since the level of contamination even upwind of a surface burst would be so high as to prevent rescue parties from working in these areas for several days at least, by which time most of the seriously injured would have died.[178] It might be possible, however, to organize rescue operations on the first day from upwind into the areas of lighter damage, perhaps fifteen miles from the center of a 20-megaton burst, where numbers of casualties would have resulted due to burns and partial collapse of frame houses.[179] Rotation of rescue teams could allow exposure to higher radiation intensities, and hence earlier rescue operations, but would increase the requirement for rescue forces. If weapons were airbursted, so that little fallout contamination resulted, rescue forces could enter blast areas soon after the detonation.

(NOTE: severe upwind fallout in the blast damaged area was measured after 10 megaton surface burst MIKE in 1952, see weapon test report WT-615 and AFSWP-507. However, this upwind fallout was a fluke due to the 82-ton steel bomb "case shock" which embedded itself deep into the crater, increasing the activity on large fallout flakes around ground zero. Data from weapons with lighter casings in Castle 1954 and Redwing 1956 disproved the MIKE upwind fallout data for practical, deliverable weapons, WT-1317. MIKE upwind fallout data was given in Glasstone ENW 1957 but was replaced with Redwing upwind fallout data in Glasstone 1962, so light upwind fallout permitted rescue.)

178. U.S. Federal Civil Defense Administration, Survival in Public Shelters, 1957, at 5-9.

179. Id. at 7-8.

The Corps of Engineers analysis of requirements for rescue squads is in U.S. Army Engineer School, Extension Subcourse 321, Civil Defense and Disaster Recovery, Ft. Belvoir, Virginia (May 1958) at 3-3 to 3-4. This document states that about 25 per cent of persons surviving in blast-damaged areas will be lightly trapped and 5 per cent heavily trapped. About 2 man-hours are required to release persons lightly trapped and 20 man-hours for those heavily trapped. Trapped casualties can survive for 4 days, and rescue squads can each produce some 768 man-hours of efficient rescue work in this time. Thus in a city where 100,000 persons remained in blast areas, about 25,000 people would be lightly trapped and 5000 heavily trapped. This would require 65 light rescue squads and 130 heavy squads, each composed of 26 men with appropriate equipment. The total rescue force requirement is thus 5070 persons, or about 50 per 1000 of target area population at the time of detonation.

One promising avenue for reducing vulnerability is to put selected industries underground. The Rand Report suggests that if we had put something like twenty per cent of our manufacturing capital underground by 1970, that economy ought to be able to withstand a 20,000-megaton, 150-city attack somewhat better than our undispersed economy in 1960 could withstand a 1500-megaton, 50-city attack.[252] A 1956 study by the Corps of Engineers discussed in some detail the problems of constructing underground industrial plants. The study pointed out that some sixty per cent of American industry lay in a quadrangle from Boston to Kansas City, and that about two-thirds of existing mine sites, suitable for underground plants, also lay in this quadrangle.[253] Experience both with underground plants in Sweden and Germany and with windowless, fully air-conditioned surface plants in this country indicates that no major personnel problems are likely to arise from working underground.[254]

252. Kahn, Rand Report, op. cit. supra note 62 at 29-30 and 11.

253. U. S. Department of the Army, Corps of Engineers, Underground Plants for Industry, Washington, GPO, 1956 at 7; see too id. at 19.

254. Id. at 37-38 and 7. For discussion of an underground metal processing and fabricating plant in Norway see Skarsgaard, Olav K.," "The Largest Underground Industry in the World." The Fifteen Nations (Number 16) at 124-125.

Prepared by Dr. William Chapman DCPA

Mor July 13, 1979

CIVIL DEFENSE FOR THE 1980's--CURRENT ISSUES

Presidential Decision (PD) 41, September 1978, established new policies for U.S. civil defense: that it should "enhance deterrence and stability and. . . reduce the possibility that the Soviets could coerce us in times of increased tension," and "include planning for population relocation during times of international crisis." The PD 41 policies are in marked contrast to previous rationales for CD, dating from 1961, which were to the effect that the program should provide "insurance" in the unlikely event of a failure of deterrence.

President Kennedy in 1961:

> But this deterrent concept assumes rational calculations by rational men. And the history of this planet, and particularly the history of the 20th century, is sufficient to remind us of the possibilities of an irrational attack, a miscalculation, an accidental war, or a war of escalation in which the stakes by each side gradually increase to the point of maximum danger which cannot be either foreseen or deterred. It is on this basis that civil defense can be readily justifiable--as insurance for the civilian population in case of an enemy miscalculation. It is insurance we trust will never be needed--but insurance which we could never forgive ourselves for foregoing in the event of catastrophe.18/

18/President John F. Kennedy, "Urgent National Needs, A Special Message to Congress," May 25, 1961.

More light was shed on issues of credibility by a national-sample survey conducted for DCPA in late 1978, involving in-depth interviews with 1620 adult Americans.31/ The results suggest that the public remains favorable in general to civil defense, and is receptive to crisis relocation in particular:

67% believe there could be crisis circumstances under which the President might urge people to evacuate high risk areas

78% believe the U.S. should have crisis relocation plans

70% say that if the President directed relocation, they would comply. (And additional people indicate they might well leave spontaneously, before any direction to do so)

75% believe the nation's communities would be helpful to evacuees

82% believe their own communities would be helpful, if asked to host evacuees. (In fact, 73% say they'd be willing to take evacuees into their own homes)

31/Nehnevasja, Jiri, Issues of Civil Defense: Vintage 1978--Summary Results of the 1978 National Survey, University of Pittsburgh, 1979.

It is significant that on September 1-3, 1939 the British moved some 1.5 million women and children from London and a few other large cities in what was a crisis evacuation, for Britain did not declare war until September 3. (Also of interest are the facts that some 2 million additional persons spontaneously evacuated at their own initiative, and that this was unsuspected at the time by the British government.) It is also worthy of note that in Hurricane Carla, in 1961, between half and three-quarters of a million people were evacuated from Gulf Coast cities without a single fatality or a major reported accident.32/

32/Senate Committee on Banking, Housing, and Urban Affairs, Hearings, Civil Defense, 95th Congress, 2d Session (January 1979) at 51-52.

> In 1939, Hitler attacked Poland, though it appears he calculated (mistakenly) that he had good chances of achieving his objectives without triggering World War II, based upon his earlier successes. In 1941 he attacked the USSR, anticipating the destruction of Bolshevism and not, eventually, of the Third Reich.
>
> In 1941 the leaders of Japan attacked the U.S., not anticipating the defeat of the empire in 1945.

--Presidential Decision 41

At all events, the PD 41 policies lay it down clearly that U.S. civil defense should ". . . enhance deterrence and stability, and contribute to perceptions of the overall U.S./Soviet strategic balance and to crisis stability, and also reduce the possibility that the Soviets could coerce us in times of crisis."

Civil Defense and the Cuban Crisis

In a 1978 interview, Steuart L. Pittman, who was Assistant Secretary of Defense for Civil Defense in 1961 to 1964, pointed out:

> [I]t is interesting that President Kennedy personally raised the civil defense question during the Cuban crisis. He was considering conventional military action against Cuba to knock out the missile sites. I understand he was the only one of the "Committee" to raise the issue of civil defense, which tells us something. He asked whether it would be practical to evacuate Miami and other coastal cities in Florida. . . . I was called into the marathon crisis meeting and had to tell him that it would not be practical; we did not have any significant evacuation plans. . . . The President dropped the idea, but shortly after the crisis was over, his personal concern over his limited civil defense options led him to sign a memorandum directing a significant speedup in the U.S. civil defense preparations. (Emphasis added.)93/

While history seldom repeats itself exactly, it does indeed "tell us something" that in the only overt nuclear confrontation the world has

93/Sullivan, Roger J. et al, The Potential Effects of Crisis Relocation on Crisis Stability, System Planning Corporation, Arlington, Virginia, September 1978 at 152-153.

yet seen, the American President was concerned about civil defense--and that the idea of population relocation during the crisis was one of his specific concerns. Certainly it is clear that in 1962, the notion of vulnerability being stabilizing held little attraction for the Chief Executive.

There is an historical precedent for a relatively rapid buildup of CD capabilities. At the time of the 1938 Munich crisis, Britain had developed civil defense plans but had little capability for actual operations. Spurred by the belief that war had become not only not unthinkable but not unlikely, Britain mounted an intensive effort.

By the time Germany attacked Poland the next September, the British were able to evacuate 1.5 million women and children from major target cities. And by the time of the August 1940 "blitz," the CD system was able to contribute substantially to Britain's ability to "take it" and to continue the war.

Following the Munich crisis, which found Britain as unprepared in civil defense as in all other areas of defense, the working of the civil defense services was reviewed by the House of Commons during a censure debate:

> Members were in a worried and critical mood, and among the charges made it was maintained that the Government had neither policy nor plans for evacuation when the country was on the verge of war. . . . [T]here was much uneasiness in Whitehall.102/

In short, there will be no public outcry for civil defense in normal times. There will be modest political profit, if any, for an Administration proposing enhanced civil defense, or a Congress approving it; the subject is not a congenial one. But should a frightening crisis find civil defense in disarray, the people (and the Congress) would surely demand to know what had been done in "the years that the locust hath eaten."103/

Summary

The PD 41 policies provide that the U.S. civil defense program should enhance deterrence and stability, and reduce the possibility of Soviet coercion during a crisis.

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102/Titmuss, Richard M., Problems of Social Policy, HMSO, London, 1950 at 30.

103/Joel 2:25. This phrase, according to Churchill, was used by Sir Thomas Inskip in referring to the period 1931-1935: The Gathering Storm, Houghton Mifflin, Boston, 1948 at 66.

Arguments Against Civil Defense and a Rebuttal

Some of the arguments made against civil defense were parodied as follows in a piece in the Harvard Crimson in 1962:

Recommendations by the Committee for a Sane Navigational Policy:

It has been brought to our attention that certain elements among the passengers and crew favor the installation of lifeboats on this ship. These elements have advanced the excuse that such action would save lives in the event of a maritime disaster such as the ship striking an iceberg. Although we share their concern, we remain unalterably opposed to any consideration of their course of action for the following reasons:

1. This program would lull you into a false sense of security.

2. It would cause undue alarm and destroy your desire to continue your voyage in this ship.

3. It demonstrates a lack of faith in our Captain.

4. The apparent security which lifeboats offer will make our navigators reckless.

5. These proposals will distract our attention from more important things, e.g., building unsinkable ships. They may even lead our builders to false economies and the building of ships which are actually unsafe.

6. In the event of being struck by an iceberg (we will never strike first) the lifeboats would certainly sink along with the ship.

7. If they do not sink, you will only be saved for a worse fate, inevitable death on the open sea.

8. If you should be washed ashore on a desert island, you could not adapt to the hostile environment and would surely die of exposure.

9. If you should be rescued by a passing vessel, you would spend a life of remorse mourning your lost loved ones.

10. The panic caused by a collision with an iceberg would destroy all semblance of civilized human behavior. We shudder at the prospect of one man shooting another for the possession of a lifeboat.

11. Such a catastrophe is too horrible to contemplate. Anyone who does contemplate it obviously advocates it.

HISTORY OF THE
SECOND WORLD WAR

Civil Defence

By

T. H. O'BRIEN

The point is of importance for students of the subject in an era in which marked 'progress' has been made in the technique of air warfare by the invention of the atomic bomb. This invention has given fresh currency to the view that 'nowadays every war is different from the one before'—which, if it were valid, would abolish any need to learn the lessons of past experience.

But in May 1917 the Germans began a series of assaults with twin-engined aircraft, called *Gothas*, which soon became severe. The daylight attack of 13th June on London by fourteen *Gothas* was the worst single attack of the war measured in casualties, which numbered 162 killed and 426 injured; 118 high explosive and incendiary bombs were dropped on the City and the East End.

The Government only gave in gradually and reluctantly to demands for public warnings in London. In July 1917 a system was introduced, under the control of the Commissioner of Police, which to those accustomed to the sirens of 1939–45 may appear somewhat primitive. Warnings were distributed partly by maroons (or sound bombs) fired into the air, and partly by policemen on foot, on bicycles or in cars carrying *Take Cover* placards and blowing whistles or sounding horns.

during 1914–18 There were in all 103 bombing raids (51 by airships and 52 by aeroplanes); and about 300 tons of bombs were dropped causing 4,820 casualties, 1,413 of which were fatal.

These totals appear small; but when they are broken down into details many different pictures emerge. The two heavy raids on London of June and July 1917, for example, together caused 832 casualties (216 fatal), which amounted to 121 casualties for each ton of bombs dropped; and these casualty figures were to have much significance for the planning authorities of the future.

13 June London raid: 118 bombs, 162 killed, 426 injured.
7 July London raid: 54 killed, 190 injured

121 casualties/ton, 31 killed/ton
(Air raids by twin-engined Gothas began in May 1917)

The Committee of Imperial Defence, created in 1904

In November 1921 the Committee asked the principal Service experts to report on the problem of possible future air attack on the United Kingdom. This report, which appeared the next year, accepted the conclusions of the Air Staff about future air attack, which were briefly as follows.

France's Air Force could drop an average weight of 1,500 tons of bombs on Britain each month by using only twenty bombing days in the month and only fifty per cent of its aircraft. London, which would be an enemy's chief objective, could be bombed on the scale of about 150 tons in the first 24 hours, 110 tons in the second 24 hours, and 75 tons in each succeeding 24 hours for an indefinite period. It was to be anticipated that an enemy would put forth his maximum strength at the outset.

Page 14: on 15 May 1924, the Air Raid Precautions (ARP) Sub-Committee first met, chaired by Sir John Anderson.

The serious picture thus presented assumed its darkest tones when the Air Staff proceeded to estimate casualties. The 300 tons of bombs dropped in the 1914–18 attacks, the experts pointed out, had caused 4,820 casualties, or 16 per ton of bombs. The 832 casualties of the two big daylight attacks on London in the summer of 1917, however,

produced an average of 121 casualties per ton; and sixteen night raids on London in 1917–18 gave an average of 52 casualties per ton.[1] After weighting these figures with various factors, the experts concluded that 50 casualties (one-third of which would be fatal) per ton formed a reasonable estimate of casualties caused by air attacks of the future on densely-populated areas. For other areas this figure should be reduced in proportion to the actual density of population.

In March 1927 the committee was faced with two matters

Royal Charter incorporating the British Broadcasting Corporation, *Wireless Broadcasting*, Cmd. 2756, 1926.

The Chemical Warfare Research Department had been making experiments to determine how long persons could remain under certain conditions in a 'gas-proof' room; and had prepared a handbook, *The Medical Aspects of Chemical Warfare*, now on sale to the public.

The first of the matters just referred to was a broadcast in February by Professor Noel Baker, on 'Foreign Affairs and How They Affect Us'. This, read in cold print at a distance of twenty years, appears as an attempt to rouse the British public to realisation of the horrors of future war, and to enlist its support for the disarmament negotiations at Geneva. The Professor quoted Mr Baldwin's speech to the Classical Association in the Middle Temple hall, 'Who in Europe does not know that one more war in the West and the civilisation of the ages will fall with as great a shock as that of Rome?' He painted a picture of gas attack from the air in another war and claimed, 'all gas experts are agreed that it would be impossible to devise means to protect the civil population from this form of attack'. The Chemical Warfare Research Department emphatically disputed the accuracy both of the details of the picture and of this general statement. They considered it unfortunate that statements of this nature should have been broadcast to the public, particularly after the Cabinet's decision that the time was not ripe for education of the public in defensive measures.

The committee discussed whether to draw the B.B.C.'s attention to this talk. The Corporation, only a few months old, was then prohibited by the Postmaster-General's instructions from broadcasting 'matter on topics of political, religious or industrial controversy'; but the Post Office representative pointed out this did not mean that his Department was prepared to undertake censoring programmes. The committee, not wishing to incur the obligation to approve in advance all proposed broadcasts relating to their field of study, decided to take no action with respect to the talk in question.

Gas was the risk most prominently associated in the public mind with future air attack, as was demonstrated a few weeks before the school opened by British reaction to Italy's use of mustard and other gases against Abyssinia.[4]

[4] According to the *Annual Register, 1936* (p. 27), 'feeling in England could hardly contain itself when the Italians were reported to be using poison gas against both soldiers and civilians'.

A final matter which concerned gas-masks belongs perhaps more properly to the topic of public reactions to A.R.P. Early in 1937 some scientific workers at Cambridge University, who described themselves as the 'Cambridge Scientists' Anti-War Group' and their function as that of acting as 'a technical and advisory body to national and international peace movements', published a book attacking the Government's A.R.P. plans.[1] This body had studied the official advice about the 'gas-proofing' of rooms, the civilian mask, and extinguishing incendiary bombs, and then conducted some experiments. It claimed to have shown that the measures officially proposed were ineffective or inadequate, and implied that these constituted deception of the public.

It has been noticed that as 1937 opened the Government was taking steps to make A.R.P. plans more widely known to the public;[2] and this deliberate challenge found a sympathetic echo in various quarters, and caused it some concern. Questions about the Cambridge experiments were asked in Parliament, for example on the occasion of the announcement of the new Wardens' Service; sections of the Press began a critical campaign, and questions were put to officials trying to build up A.R.P. services over the country. The Government's reply was that the experiments were academic (in the sense of removed from reality), and based on fallacious assumptions about the conditions likely to be met in actual warfare.[3] In spite of pressure the authorities refused to engage in technical controversy with the scientists in question and within a few months the agitation subsided. At the close of the year, however, a report on the official experiments (in supervision of which the Chemical Defence Committee had been helped by eminent scientists not in Government employment) was circulated to local authorities and otherwise made public.

[1] *The Protection of the Public from Aerial Attack* (Left Book Club Topical Book, Victor Gollancz Ltd, 1937.)

[2] p. 71.

[3] H. of C. Deb., Vol. 320, Col. 1348, 18th February 1937.

A demonstration of how to deal with the light incendiary bomb had been included in the Anti-Gas School curriculum in November 1936; and in February 1937 the Home Office Fire Adviser staged a demonstration at Barnes at which bombs were successfully controlled and fires extinguished by teams of girls with only short training. At an exercise held later at Southampton a group of air raid wardens carried out this function with such success that the Department concluded it must aim to train all householders in the handling of incendiary bombs.

Air Staff had raised their estimate of the weight of bombs which an enemy (now Germany) might drop on Britain during the first stages of an attack from 150 tons *per diem* to no less than 600 tons. The committee proceeded, as their predecessor of 1924 had done, to question the experts and then to accept their hypothesis.[1] The estimate of over 600 tons of bombs *per diem* during the first few weeks (which took account of Britain's various potential forms of counter-offensive) also embraced the possibility of a special bombing effort on the part of the enemy in the first 24 hours which might amount to 3,500 tons. Consideration had to be taken not only of this greatly increased weight of attack but of new methods of attack for which past experience afforded no precedents. The measure offered by the accepted air raid casualty figure of 1914–18 (50 per ton of bombs, 17 of which were killed and 33 wounded) was subject to the *caveat* that modern bombs were more effective. The committee pointed out that an arithmetical computation on this basis for the scale of attack at 600 tons *per diem* would indicate casualties of the order of 200,000 a week, of which 66,000 would be killed.

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[1] The new estimated scale of attack had been referred to the Home Defence Committee, and was not approved by the Committee of Imperial Defence until 28th October 1937.

The 25 million civilian gas-masks accumulated by the opening of 1938 were, from various points of view, one of the most tangible assets of the A.R.P. Service.

The invention of a practical household shelter—to be quickly known as the 'Anderson'—had transformed the possibilities hitherto envisaged for protection of homes against air attack. The Government had undertaken to supply these shelters, as well as steel fittings for strengthening basements, free to some 2½ million families.

The 'Anderson' had originally been conceived as a shelter to be erected inside the average small working-class home. But the experts soon discarded this idea as open to various objections, including the probability that occupants would be trapped by the fall of their house and killed by fire or escaping coal-gas. During Munich householders had been advised to dig trenches in their yards or gardens, and now, by an extension of this plan, the 'Anderson' was designed as an outdoor or surface shelter. It consisted of fourteen corrugated steel sheets weighing, with other components, about 8 cwt. A corrugated steel hood, curved for greater strength, would be sunk some two feet in the ground and covered with earth or sandbags.

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The programme for manufacture and distribution by the end of 1939–40 of 2½ million 'Andersons' to protect about 10 million citizens was being steadily carried through.

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householders in May in the form of a booklet, *Your Home as an Air Raid Shelter.*[1] This stated that an ordinary soundly-built house would offer very substantial protection; and it gave those unable to build some form of shelter much detailed guidance on the preparation of refuge rooms, the protection of windows and so on.

[1] H.S.C. 98/40, 22nd May 1940.

416 *Ch. X: THE TIDES OF BATTLE*

16 April 1941: heaviest London air raid of WWII:

On the night of 16th-17th some 450 aircraft made the heaviest raid so far on the capital, dropping 446 tons of high explosive and 150 tons of incendiaries and causing more casualties—about 1,180 killed and 2,230 badly injured—than in any previous attack.[1] Over 2,250 fires were started; and the centre and south of the metropolis bore the brunt of the attack.

[1] German records show the much higher figures of 685 aircraft, 890 tons of H.E. and 4,200 incendiary canisters dropped. This attack proved the worst on London of the war in terms of weight of bombs dropped, casualties inflicted and the number of fires caused.

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These occasions apart, the attack was predominantly of the tip and run or—as it was sometimes called—'the scalded cat' variety. The worst single incident of the year took place on 3rd March at Bethnal Green Tube shelter when, ironically enough, no attack was in progress on this particular area. A night attack of moderate proportions was being made on London, and warnings had sounded. A woman among the crowd entering this shelter, encumbered by a baby and a bundle, fell, causing those pressing behind her to tumble in a heap and the death by suffocation of no less than 178 persons. **3 March 1943**

508 *Ch. XII: SHELTERS*

In London a periodical count was made of shelterers, usually once a month; but this took place on a single night which was not necessarily typical. In addition, the population was continually fluctuating owing to evacuation, the call-up to the Forces and war damage. The first shelter census in Metropolitan London, taken early in November 1940, showed that 9 per cent. of the estimated population spent the night in public shelters, 4 per cent. in the Tubes and 27 per cent. in household shelters—in all, only 40 per cent. in any kinds of official shelter. In September and October this proportion was probably a good deal higher. Later, as the London public became accustomed to raids, the figures dropped.

Experience of raids also led to the introduction of an entirely new type of household shelter. 'Andersons', though structurally satisfactory, had not originally been intended for sleeping and became in many cases unfit for winter occupation. Domestic surface shelters were very cramped when used for sleeping and were in some places not popular, and strengthened domestic basements had been neither very successful nor widely used. After night raiding had ceased to be a novelty, many people preferred to stay in their houses rather than to go out of doors even to their own domestic shelters. The 'Anderson', it will be recalled, had at first been envisaged as an indoor shelter. Since many people were now determined to remain in their homes, it had become necessary to introduce some indoor shelter which might reduce the risk of injury from falling masonry and furniture. The fact that many who had hitherto sheltered under their staircases or furniture had been rescued unhurt from the wreckage of houses suggested that extra protection might be given by a light structure on the ground floor.

By the end of 1940 two designs had been produced. The first, later known as the 'Morrison' shelter, had a rectangular steel framework 6 ft. 6 in. long, 4 ft. wide and about 2 ft. 9 in. high. The sides were filled in with wire mesh, the bottom consisted of a steel mattress and the top was made of steel plate an eighth of an inch thick, fastened to the framework by bolts strong enough to withstand a heavy swinging blow. The shelter, which could be used as a table in the daytime, could accommodate two adults and either two young children or one older child, lying down. Experiments showed that it would carry the debris produced by the collapse of two higher floors.

The Prime Minister showed great interest in these shelters the first of which, in fact, were erected in No. 10 Downing Street.[2] In January 1941 the Cabinet approved the manufacture of 400,000, providing protection for perhaps 1,200,000 people.[3]

In February contracts had been placed for 270,000 shelters, and another order for the same number was placed in April (thus exceeding the 400,000 originally approved). Two further orders for 270,000 were placed at the end of July and the end of September.

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[1] Instructions were given in a pamphlet, *How to put up your Morrison shelter*, on sale to the public.

[2] One with a flat top and one with a curved top were erected in No. 10 Downing Street. The Prime Minister was at first inclined to favour the curved design but he afterwards recognised the advantages of the flat top, which would allow the shelter to be used as a table, and gave his approval to both designs.

[3] It was estimated that each 'Morrison' would use over 3 cwt. of steel, and that about 65,000 tons would be needed for the 400,000 shelters. This proved to be an underestimate since the table shelter, as finally designed, actually weighed 4.43 cwt.

In June a revised version of *Your Home as an Air Raid Shelter* was issued with the title *Shelter at Home*. This included information about three types of shelter which could be put inside refuge rooms—the 'Morrison', a commercially made steel shelter, and a timber-framed structure designed by the Ministry of Home Security.

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It was assumed that to be effective in attacks by pilotless aircraft or long-range rockets, shelters would have to be easily accessible. Yet a review of London shelter in the summer of 1943 had shown that large numbers still had no domestic shelter, and that many thousands would be unable to reach a public shelter quickly. Though the obvious solution to the problem was the 'Morrison', production of these had stopped twelve months before; and in order to build up a reserve issue had been discontinued in various areas, including London. At the beginning of October it was decided that another 100,000 'Morrisons' should be manufactured and that the reserves held in Scotland, the North of England, the Midlands and North Wales should be moved to the vicinity of London and to the Reading and Tunbridge Wells Regions, from where they could, if necessary, be used to supply London.

Large-scale redistribution of 'Morrisons' and the procurement of new ones called for a substantial administrative effort. Nonetheless, most reserves were transferred during the autumn, and by the end of January 1944 some 12,000 had deen distributed to London householders. At the beginning of this year, however, preparations for the Allied invasion of Europe began to choke the railways with more important traffic, and it became impossible to transport new shelters from manufacturers in the north of England. This difficulty, combined with delays in the production of spanners and nuts, meant that no new shelters could be delivered before late February or early March, when it was expected that the V-weapon attacks would have begun. Arrangements were made for some to be shipped coastwise to London; but in mid-February the contract for the remaining 'Morrisons' (about 20,000) was cancelled. **V2 THREAT:**

648 *Ch. XV: CHALLENGE OF 'V' WEAPONS*

On 11th September the War Cabinet considered the need for a revival of the plan (known as the 'black move') to evacuate a proportion of the staffs of Government Departments from London. The numbers now involved in such an exodus of the war-expanded Departments would be high, and difficulties of communications, transport, accomodation and billeting again seemed overwhelming; it was, therefore, agreed that the more practical course would be to devise measures such as 'citadel' accommodation to enable essential work to continue in London. The production of the further 100,000 'Morrison' shelters and the work on the reinforcement of street shelters proposed by the Home Secretary were also authorised.

As far as shelter policy was concerned, orders had been placed in September 1943 for an additional 100,000 indoor table shelters and existing stocks were moved into the areas of probable attack. Difficulties of manufacture and transport had led to poor deliveries of 'Morrisons', and it seemed unlikely that more than half of the additional shelters ordered would be available by the time attacks were likely to begin. As the remainder would probably arrive too late to be of any use, contracts for the shelters were to be reduced by about 25,000. On the question of deep Tube shelters it had been agreed earlier that priority in the allocation of space would have to be given to the essential machinery of government. The Ministry of Works worked out a plan to shelter those government staffs not already provided for in the strengthened basements of their own steel-framed buildings. All shelter plans, the reader will recall, were given valuable impetus by the resurgence of 'conventional' attack on London and the south in the 'Little Blitz' of early 1944.

V1 flying bomb:

Flying glass was a special danger and people were warned to take cover on the sound of a bomb diving or the engine stopping, and later on the sounding of imminent danger warnings. The vast damage to houses inevitably caused great domestic upheavals. To begin with there was a definite decline in production in London, due to an increase in the rate of absenteeism, to loss of time in actual working hours through workers taking shelter and to lowered efficiency through loss of sleep and anxiety. The extension of the industrial alarm system and the increase in the labour force repairing damaged property, however, soon reduced these early signs of disturbance. Within a few weeks evacuees were returning to London, shelters were less full and most people were going about their normal tasks as usual.

For the civil defence services the new weapon demanded new tactics. In many ways these attacks were much easier to contend with than ordinary bombing. Firstly, most of the incidents were isolated, so that services could be directed in strength to the affected area without constant competing demands on the personnel at every turn. Secondly, the fall of the bombs could be spotted within a matter of seconds by high-placed observation posts either by night or by day, so that rescue and first aid squads could be on the spot very quickly. Thirdly, the penetrative power of this weapon was slight so that incidents rarely involved the complications of broken gas, electricity or water mains, and there was also little tendency for fires to break out. On the other hand the bombs could fall at any time in crowded thoroughfares; the proportion of casualties in the streets was much higher than ever before while the proportion of trapped casualties was lower. At night time, since there were no German eyes above, the use of artificial light was less restricted and searchlights could be used for rescue work.

APPENDIX IV

Major night attacks on United Kingdom cities and towns from 7th September, 1940 to 16th May, 1941

Target Area	*Number of Major Attacks*[1]	*Tonnages of H.E. Aimed*
London	71	18,291
Liverpool-Birkenhead	8	1,957
Birmingham	8	1,852
Glasgow-Clydeside	5	1,329
Plymouth-Devonport	8	1,228
Bristol-Avonmouth	6	919
Coventry	2	818
Portsmouth	3	687
Southampton	4	647
Hull	3	593
Manchester	3	578
Belfast	2	440
Sheffield	1	355
Newcastle-Tyneside	1	152
Nottingham	1	137
Cardiff	1	115

[1] The enemy's definition of a 'major attack', i.e. one in which 100 tons or more of high-explosive bombs were successfully aimed at the target, has been adopted for this table.

Issued for the Ministry of Home Security
by the Ministry of Information

FRONT LINE

1940-41

The Official Story of the
CIVIL DEFENCE
of Britain

1942
London: His Majesty's Stationery Office

So far was all this from panic that it took three months for the population of the twenty-eight central boroughs to drop by about 25 per cent. from a little over 3,000,000 (the figure before heavy bombing began) to 2,280,000 at the end of November. In a group of the most heavily bombed eastern boroughs the pre-war population of 800,000 had fallen to 582,000 before the blitz began; for four months it had dropped steadily to 444,000; by 31st December a fall of 23 per cent. These figures do not spell panic, and a further substantial fall in 1941, after continuous heavy raiding had ceased, completes the evidence that those who went did so in cold blood, for practical reasons as valid for their hard-pressed city as for their private selves.

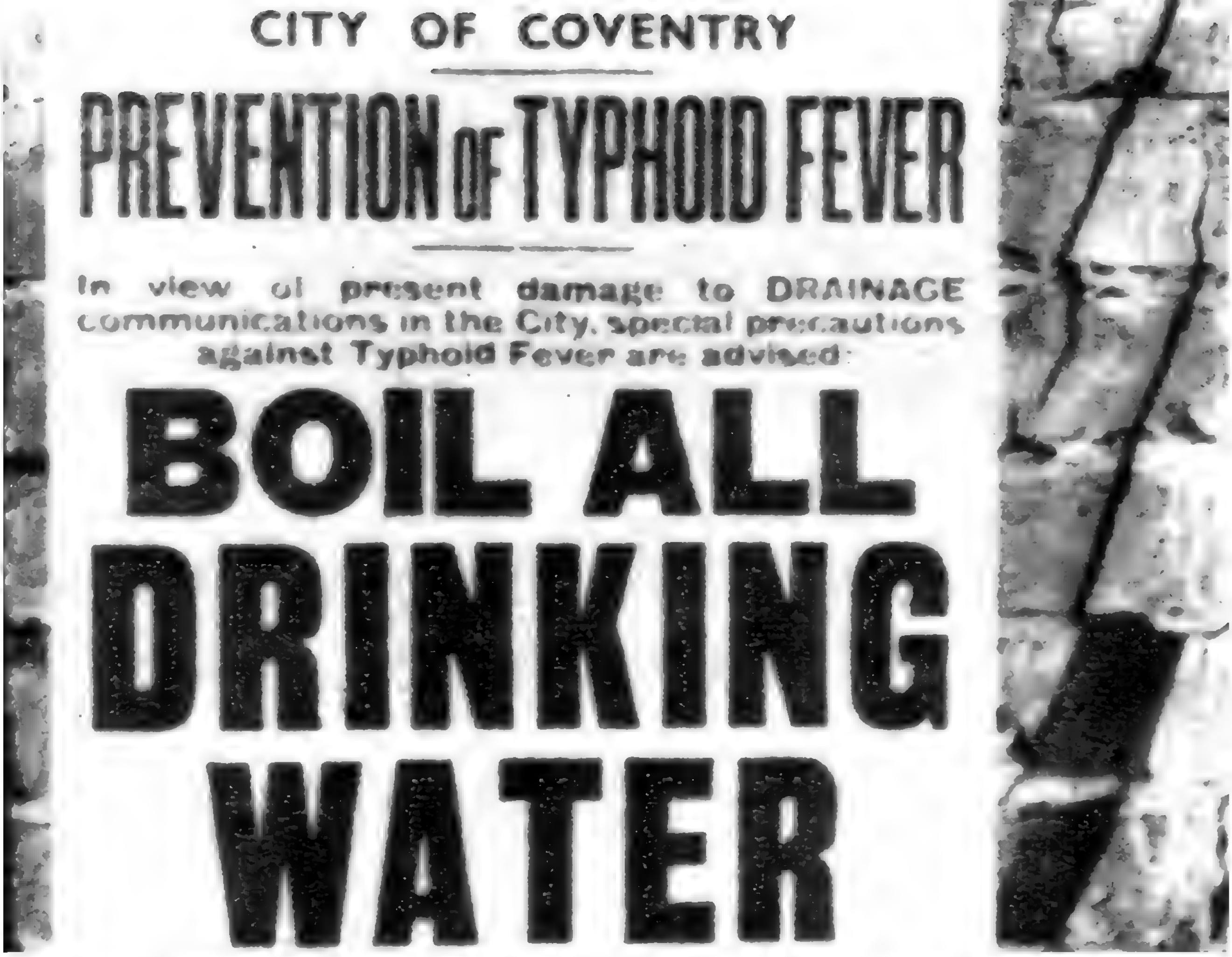
But what did all this mean to the average Londoner? In November, inner London (the county) contained some 3,200,000 people. Not more than 300,000 of these were in public shelter of any kind, half of that number at most in those larger shelters on which the limelight shone so exclusively. Nor is this all; in domestic shelter (Andersons, small brick shelters and private reinforced basements) there were no more than

1,150,000 people. Thus of every hundred Londoners living in the central urban areas, nine were in public shelter (of whom possibly four were in "big" shelters), 27 in private shelter, and 64 in their own beds—possibly moved to the ground floor—or else on duty. Particular big shelters, and for a few nights the tubes, were overcrowded, but there was public shelter for twice the number who made use of it. In outer London, with a population of some 4,600,000, there were in November 4 per cent. in public shelter, 26 per cent. in domestic shelter, and 70 per cent. at home or on duty.

In the last great war there had been outbursts of hate against the distant enemy, and shops with German names had been wrecked. This time the citizens did not stop for such things. After the first shock of realisation they found no more need for direct recrimination than does the soldier. Like him, they got on with the job and waited their chance. Neither in this nor in any other way was there a sign of instability; no panic running for shelter, no white faces in the streets (though plenty of taut, grim ones), no nerve disease. In all London, the month of October saw but twenty-three neurotics admitted to hospital. The mind-doctors had rather fewer patients than usual.

BLOCKED ROADS. The morning of 12th May: each raid sets the police still another traffic problem.

ENORMOUS CRATERS. At the Bank, where the road collapsed into the subway beneath. A temporary bridge was thrown right across it.


CITY OF COVENTRY
PREVENTION OF TYPHOID FEVER
In view of present damage to DRAINAGE communications in the City, special precautions against Typhoid Fever are advised:
BOIL ALL DRINKING WATER

The outcome may be seen in the following table, which shows coastal bombing to November, 1941, in round figures.

Town.	Number of Raids.	Civilians Killed.	Houses Damaged.
Fraserburgh ...	18	40	700
Peterhead ...	16	36	700
Aberdeen ...	24	68	2,000
Scarborough ...	17	30	2,250
Bridlington ...	30	24	3,000
Grimsby	22	18	1,700
Gt. Yarmouth ...	72	110	11,500
Lowestoft ...	54	94	9,000
Clacton	31	10	4,400
Margate ...	47	19	8,000
Ramsgate ...	41	71	8,500
Deal	17	12	2,000
Dover	53 (and shelling)	92	9,000
Folkestone ...	42	52	7,000
Hastings	40	46	6,250
Bexhill	37	74	2,600
Eastbourne ...	49	36	3,700
Brighton Hove ... }	25	127	4,500
Worthing ...	29	20	3,000
Bournemouth ...	33	77	4,000
Weymouth ...	42	48	3,600
Falmouth ...	33	31	1,100

A PENGUIN SPECIAL

THE PSYCHOLOGY OF FEAR AND COURAGE

BY

EDWARD GLOVER

(Published for Blitz air raids in 1940)

PENGUIN BOOKS

HARMONDSWORTH MIDDLESEX ENGLAND

41 EAST 28TH STREET NEW YORK U.S.A.

Real knowledge, for example, is one of the best antidotes to unreal fear. *Useful action* is also an excellent preventive, and *vigorous preparation to meet real danger* will enormously reduce unreal fear. The strength of a common purpose will do the rest. Knowledge, a common purpose, and preparedness for action. These are the remedies for faintness of heart in the face of danger.

22

Now as to preparation. You may recall that when Napoleon was asked how he was always able to give an instant decision in a crisis, he replied: "Because I constantly prepare every detail in advance." Here is a discipline you can readily cultivate. Always make a point of knowing beforehand *exactly* what you are going to do in an air raid; whether you find yourself in house, street, train, bus or shelter. Have it word perfect.

23

A

stray crowd packed into a cinema is likely to panic at the cry of "Fire." There are no common bonds between the people concerned; and there are no leaders. Each one is for himself.

34

Already we have the advantage that we are fighting not only for our lives and homes but for the immemorial cause of human liberty. But that is not enough. Provided we are united with our leaders in a common effort, real danger will never sap our morale. The greatest danger to our morale is unreal fear.

36

A. R. P.

(Air Raid Precautions)

by

J. B. S. HALDANE, F.R.S.

(Co-inventor of 1915 gas masks)

SEPTEMBER
1938

LONDON

VICTOR GOLLANCZ LTD

1938

keyholes and cracks in the wall or between the floor-boards are to be filled with putty or sodden newspaper.

The windows must be specially protected against breakage by blast or splinters.

(Plastic sheets and duct tape for broken windows)

How far are these precautions effective? In 1937 a committee of the Cambridge Scientists' Anti-War Group published a book[1] in which it was stated that no ordinary room is anywhere near gas-proof.

[1] *The Protection of the Public from Aerial Attack.*

Error of Cambridge Scientists' Anti War Group:

The real criticism is as follows. It is unlikely that there would be a lethal concentration of gas out of doors for a long period. The wind carries gas away, and in cities there are vertical air currents even in calm weather. If many tons of bombs could be dropped in the same small area either at once or in succession this would not be so. But given any sort of defence bombs will be dropped more or less at random.

Suppose we had out of doors during 10 minutes a phosgene concentration of one part in 10,000, which would be fatal in a few breaths to people in the street, the concentration inside would never rise as high as $\frac{1}{15}$ of this value[1] if the leakage time were $2\frac{1}{2}$ hours, which is rather low. (Hence protection factor = 15)

[1] Since 10 minutes is $\frac{1}{15}$ of $2\frac{1}{2}$ hours.

Many of the questions which are asked concerning Air Raid Precautions are unanswerable in the form in which they are put. If I am asked "Does any gas mask give complete protection against phosgene" the only literally true answer is "No." One could not live in a room full of pure phosgene in any of them. And one would be killed if a hundred-pound phosgene bomb burst in the room, even when wearing the very best mask. But one would be safe in a phosgene concentration of one part per thousand, of which a single breath would probably kill an unprotected man. Hence in practice such a mask is a very nearly complete protection.

1. NON-PERSISTENT GASES, such as phosgene. They can be dropped in bombs which burst, and suddenly let loose a cloud of gas, which is poisonous when breathed, but which gradually disperses. If there is a wind the dispersal is very quick; in calm, and especially in foggy weather, it is much slower. These gases can penetrate into houses, but very slowly. So even in a badly-constructed house one is enormously safer than in the open air. Even the cheapest type of gas mask, *provided it fits properly and is put on at once*, gives good protection against them (see Chapter IV).

2. PERSISTENT GASES, such as mustard gas. Mustard gas is the vapour of an oily liquid, which I shall call mustard liquid. So far as I know this has not been dropped from aeroplanes in bombs on any great scale. It was used very effectively by the Italians in Abyssinia, who sprayed it in a sort of rain from special sprayers attached to the wings of low-flying aeroplanes.

If the mustard liquid could be sprayed evenly, things would be far more serious. All the outside air of a large town would be poisonous for several days. But this would only be possible if the spraying aeroplanes could fly to and fro over the town in formation, and at a height of not more than 300 feet or so. A fine rain of mustard liquid would probably evaporate on its way to the ground, or blow away, if it were let loose several thousand feet up in the air. Spraying from low-flying aeroplanes was possible in Abyssinia because the Abyssinians had no anti-aircraft guns and no defensive aeroplanes. It would probably not be possible in Britain.

THE HAMBURG DISASTER. Fantastic nonsense has been talked about the possible effects of gas bombs on a town. For example, Lord Halsbury said that a single gas bomb dropped in Piccadilly Circus would kill everyone between the Thames and Regent's Park. Fortunately, although no gas bombs have been dropped in towns in war-time, there are recorded facts[1] which give us an idea of what their effect would be. On Sunday, May 20th, 1928, at about 4.15 p.m., a tank containing 11 tons of phosgene burst in the dock area of Hamburg.

Casualties occurred up to six miles away. In all 300 people were made ill enough to be taken to hospital, and of these ten died. About fifty of the rest were seriously ill. These casualties are remarkably small.

[1] Hegler, *Deutsche Medizinische Wochenschrift*, 1928, p. 1551.

WHY GAS WAS NOT USED IN SPAIN

In view of the terrible stories as to the effects of gas, many people are surprised that it has not been used in Spain. First, why was it not used against the loyalist army? Secondly, why was it not used against towns? The soldiers had respirators after about February 1937, but were not well trained in their use, and often lost them. Very few civilians had any respirators at all.

Gas was not used in the field for several reasons. The main reason is that the number of men and guns per mile was far less than on the fronts in the Great War. Gas is effective if you have a great deal of it,

but the amount needed is enormous. Thus during the night of March 10-11th, 1918, the Germans fired about 150,000 mustard-gas shells into an area of some twenty square miles south-west of Cambrai. If most of the air in a large area is poisoned the effects are serious. But if a few gas shells are fired or a few cylinders let off, the gas soon scatters and ceases to be poisonous, and a man can often run to a gas-free place, even without a mask, before he is poisoned.

Gas was not used against the towns for this reason, and for another, which is very important. Gas only leaks quite slowly into houses, particularly if there are no fires to make a draught, and draw in outside air; and there is very little fuel in loyal Spain.

PANIC

Panic can be a direct cause of death. If too many people crowd into a shelter, especially one with narrow stairs leading to it, they may easily be crushed to death. In January 1918 fourteen people were killed in this way at Bishopsgate Station in London, and sixty-six were killed in a panic in one of the Paris Underground stations as the result of a false gas alarm.

(Bishopsgate Station incident: 28 January 1918)

BACTERIA AND OTHER MICROBES

It is possible that these will be used in some kind of spray or dust. The difficulty is a technical one. It is easy to disperse many solids as smoke. But this needs heat, and cooked bacteria are harmless. Many

bacteria are killed even by drying. And once bacteria are on the ground they generally stay there. Possibly pneumonic plague or some other air-borne disease might be started by a dust-bomb. Cholera bacilli might be dropped in a reservoir. But they would probably be stopped by filters, and even without this would be likely to die before they reached the houses.

A million fleas weigh very little, and could easily be dropped. In theory they could be infected with plague. In practice this would need a staff of hundreds of trained bacteriologists, and huge laboratories. So with other possible means of infection. Some may very well be tried, if only to create a panic, but I would sooner face bacteria than bombs.

Certain pacifist writers are severely to blame for our present terror of air raids. They have given quite exaggerated accounts of what is likely to happen.

So long as civilian populations are unprotected, criminal States will continue to murder the citizens of their weaker neighbours and to blackmail the stronger.

PHYSICAL PROPERTIES OF A GAS-CLOUD. Every student of chemistry learns that a heavy gas such as chlorine can be poured from one vessel into another almost like water, whilst a light gas such as hydrogen rapidly rises. Now all the poisonous gases and vapours used in war are heavier than air, so it is thought that they would inevitably flood cellars and underground shelters, and that on the first floor of a house one would not be safe.

But within a short time it would be mixed with many times its volume of air. Now air containing one part in 10,000 of phosgene is extremely poisonous. But its density exceeds that of air by only one part in 4,000.

GAS-MASKS, AND GAS-PROOF BAGS FOR BABIES

THE EARLIEST GAS-MASKS made in 1915, relied on chemical means to stop chlorine, which was the first gas used. A cloth soaked with sodium phenate or various other compounds will stop chlorine on its way through. But it would not stop carbon monoxide, mustard gas, or many other gases. The terrible prospect arose that it would be necessary to devise a new chemical to stop each new gas. There would be a continual series of surprise attacks with different gases, each successful until a remedy was found, and each involving the death of thousands of men.

It is a most fortunate fact that the majority of vapours can be removed from air, not by chemical combination, but by a process called adsorption, which is non-specific. For example lime will stop an acid gas such as carbon dioxide, and woollen cloth soaked in acid will stop an alkaline gas such as ammonia. No single chemical will combine with both.

But charcoal, silica, and various other substances, when properly prepared, will take up vapours of different chemical types. The molecules form a very thin liquid layer on the surface of the adsorbent, as indeed they do on glass or metals. But charcoal is full of pores and has an enormous surface per unit of weight; so it can take up a great deal of gas.

The main characteristic in a vapour which renders it adsorbable is that it should be the vapour of a liquid with a high boiling point. Thus carbon monoxide boils at–190° C, and is hardly adsorbed at all. Phosgene boils at 8° C and is fairly easily adsorbed. Mustard gas boils at 217° C and is very easily adsorbed indeed. This has a lucky consequence. It is quite sure that there are no unknown poisonous gases with a boiling point as low as that of carbon monoxide. For only a substance with very small molecules can have so low a boiling point. And chemists have made all the possible types of very small molecules. It is unlikely that there are any unknown poisonous gases with as low a boiling point as phosgene, though it is just possible. But if there are they will probably be stopped by charcoal. There may very possibly be some vapours of high boiling point more poisonous than mustard gas. But if so I am prepared to bet a thousand to one that charcoal will stop them all.

FINAL REPORT

11 March 1963

Recovery and Decontamination Measures after Biological and Chemical Attack

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

Contract OCD-OS-62-183

Prepared for
Office of Civil Defense
Department of Defense

by

Science Communication, Inc.
1079 Wisconsin Avenue, N. W.
Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem — the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

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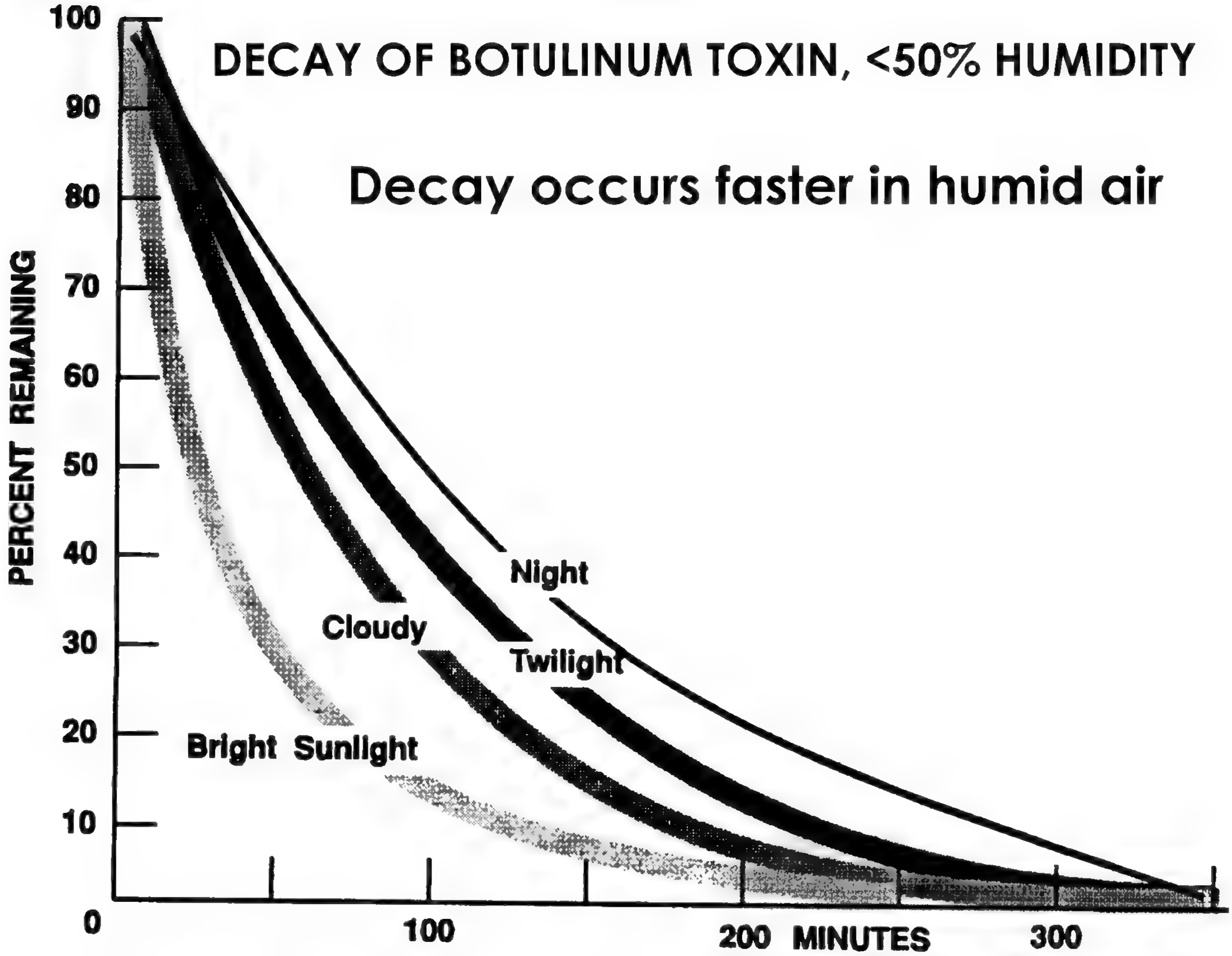
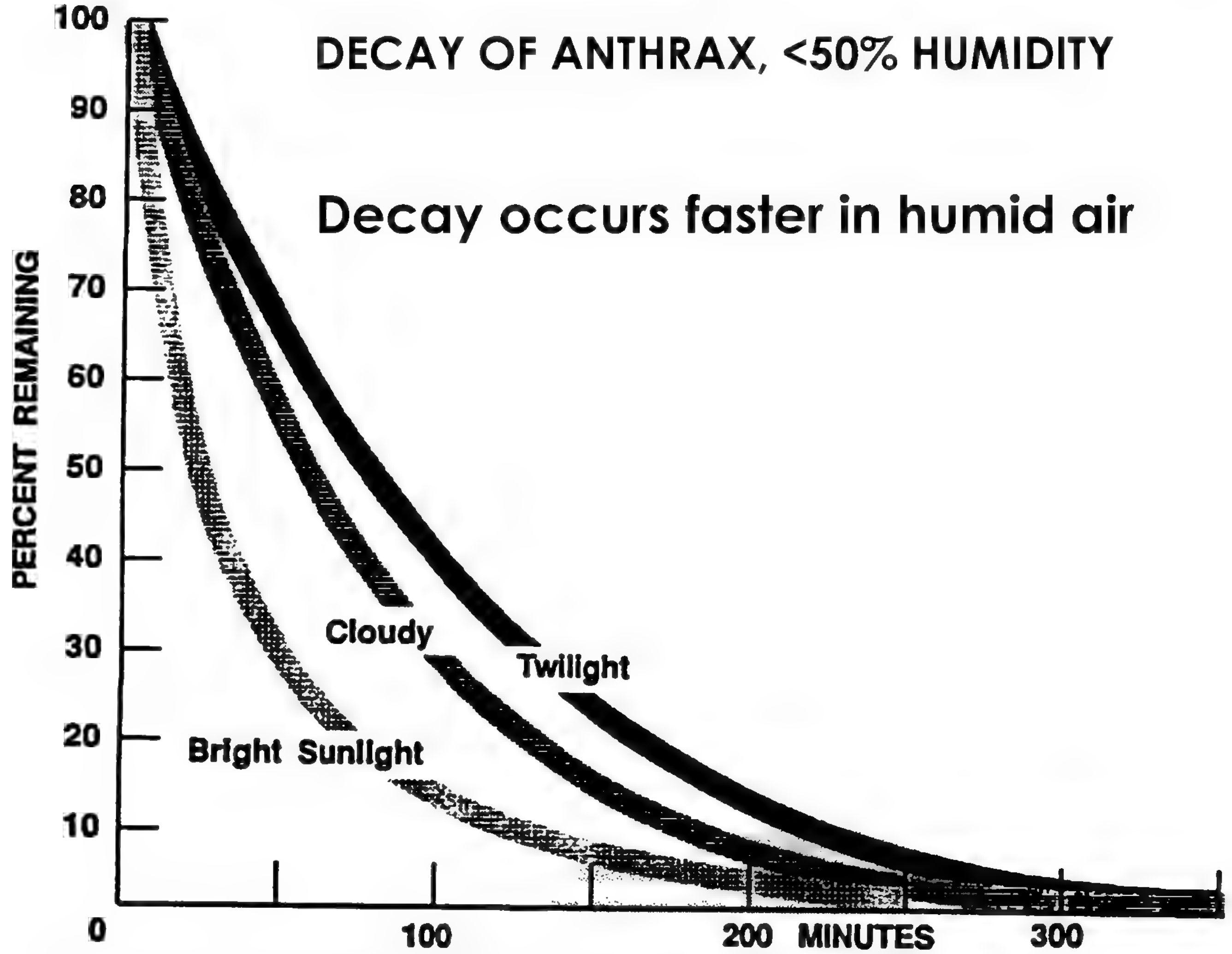


U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.



U.S. Army Field Manual FM 3-3 (1992), Fig. B-1.

Chemical and biological contamination avoidance, FM 3-3 (1992)

10 grams/square meter

TABLE 1-2. Chemical Agent Persistency in Hours on CARC Painted Surfaces.

Temperature		GA/ GF[1]	GB[2,3]	GD[2,3]	HD[1]	VX[2,3]
C°	F°					
-30	-22	*	110.34	436.69	**	***
-20	-4	*	45.26	145.63	**	***
-10	14	*	20.09	54.11	**	***
0	32	*	9.44	22.07	**	***
10	50	1.42	4.70	9.78	12	1776
20	68	0.71	2.45	4.64	6.33	634
30	86	0.33	1.35	2.36	2.8	241
40	104	0.25	0.76	1.25	2	102
50	122	0.25	0.44	0.70	1	44
55	131	0.25	0.34	0.51	1	25

NOTE

1 For grassy terrain multiply the number in the chart by 0.4.
2 For grassy terrain multiply the number in the chart by 1.75.
3 For sandy terrain multiply the number in the chart by 4.5.
* Agent persistency time is less than 1 hour.
** Agent is in a frozen state and will not evaporate or decay.
*** Agent persistency time exceeds 2,000 hours.

COMPARATIVE VOLATILITY OF CHEMICAL WARFARE AGENTS

Agent	Volatility (mg/m^3) at 25°C
Hydrogen cyanide (HCN)	1,000,000
Sarin (GB)	22,000
Soman (GD)	3,900
Sulfur mustard	900
Tabun (GA)	610
Cyclosarin (GF)	580
VX	10
VR ("Russian VX")	9

Data source: US Departments of the Army, Navy, and Air Force. *Potential Military Chemical/Biological Agents and Compounds*. Washington, DC: Headquarters, DA, DN, DAF; December 12, 1990. Field Manual 3-9. Naval Facility Command P-467. Air Force Regulation 355-7.

SIGNS AND SYMPTOMS REPORTED BY TOKYO HOSPITAL WORKERS TREATING VICTIMS OF SARIN SUBWAY ATTACKS*

Symptom	Number/percentage of the 15 physicians who treated patients at UH		Number/percentage of 472 care providers reporting symptoms at SLI	
Dim vision	11	73%	66	14%
Rhinorrhea	8	53%	No information	
Dyspnea (chest tightness)	4	27%	25	5.3%
Cough	2	13%	No information	
Headache	No information		52	11%
Throat pain	No information		39	8.3%
Nausea	No information		14	3.0%
Dizziness	No information		12	2.5%
Nose pain	No information		6	1.9%

*Data reflect reported survey of self-reported symptomatology of physicians at the University Hospital of Metropolitan Japan emergency department and all hospital workers at Saint Luke's International Hospital exposed to sarin vapors from victims of the Tokyo subway attack.

SLI: Saint Luke's International Hospital

UH: University Hospital

Data sources: (1) Nozaki H, Hori S, Shinozawa Y, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. *Intensive Care Med*. 1995;21:1032-1035. (2) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 1: community emergency response. *Acad Emerg Med.* 1998;5:613-617. (3) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 2: Hospital response. *Acad Emerg Med.* 1998;5:618-624.

TABLE 21-3

MANAGEMENT OF MILD TO MODERATE NERVE AGENT EXPOSURES

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	**Symptoms**	**Age**	**Dose**	**Age**	**Dose**
• Tabun • Sarin • Cyclosarin • Soman • VX	• Localized sweating • Muscle fasciculations • Nausea • Vomiting • Weakness/floppiness • Dyspnea • Constricted pupils and blurred vision • Rhinorrhea • Excessive tears • Excessive salivation • Chest tightness • Stomach cramps • Tachycardia or bradycardia	Neonates and infants up to 6 months old	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.25 mg AtroPen† and **2-PAM** 15 mg/kg IM or IV slowly to max 2 g/hr	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.5 mg AtroPen and **2-PAM** 25 mg/kg IM or IV slowly to max 2 g/hr	Young children (30 days old–5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 1 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Children (≥ 5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 10 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 2 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8 hr period or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg

2-PAM: 2-pralidoxime
IM: intramuscular
IO: intraosseous
IV: intraveneous
PDH: Pediatrics Dosage Handbook
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 minutes until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible.
†Meridian Medical Technologies Inc, Bristol, Tenn.
Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtropPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio; Lexi-Comp Inc: 2006.

TABLE 21-4

MANAGEMENT OF SEVERE NERVE AGENT EXPOSURE

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	Severe Symptoms	Age	Dose	Age	Dose
• Tabun • Sarin • Cyclosarin • Soman • VX	• Convulsions • Loss of consciousness • Apnea • Flaccid paralysis • Cardio-pulmonary arrest • Strange and confused behavior • Severe difficulty breathing • Involuntary urination and defecation	Neonates and infants up to 6 months old	**Atropine** 0.1 mg/kg IM/IV/IO or 3 doses of 0.25mg AtroPen[†] (administer in rapid succession) and **2-PAM** 25 mg/kg IM or IV slowly, or 1 Mark I[†] kit (atropine and 2-PAM) if no other options exist	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 0.5mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, or 1 Mark I kit (atropine and 2-PAM) if no other options exist	Young children (30 days old–5 yrs and adults	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 1mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, 1 Mark I kit (atropine and 2-PAM) up to age 7, 2 Mark I kits for ages > 7–10 yrs	Children (≥ 5 yrs old)	**Diazepam** 0.05-0.3 mg/kg IV to a max of 10 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 6 mg IM or 3 doses of 2 mg AtroPen (administer in rapid succession) and **2-PAM** 1800 mg IV/IM/IO, or 2 Mark I kits (atropine and 2-PAM) up to age 14, 3 Mark I kits for ages ≥ 14 yrs	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8-hr period, or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg

IM: intramuscular
IO: intraosseous
IV: intravenous

*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 min until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible. [†]Meridian Medical Technologies Inc, Bristol, Tenn.

Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtroPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio: Lexi-Comp Inc; 2006.

French family at Marbache, Meurthe et Moselle, France, September 1918. Gas masks were compulsory in the village, due to nearby gas attacks. Photo is the frontispiece of the October 1921 reprint of Will Irwin's book "The Next War" (Dutton, N.Y., 19th printing Oct 1921; first published April 1921.)

J. Davidson Pratt, "Gas Defence from the Point of View of the Chemist" (Royal Institute of Chemistry, London, 1937): "... during the Great War, French and Flemish ... living in the forward areas came unscathed through big gas attacks by going into their houses, closing the doors - the windows were always closed in any case - and remaining there..."

London 1941 baby gas mask drill

Hand pumped
(asthmatic)
Baby's
Hospital patient's
Police
/warden
Civilian
Soldier's
until 1942
Small child's
(mickey mouse)

Breathe Freely!

THE TRUTH ABOUT POISON GAS

JAMES KENDALL

M.A., D.Sc., F.R.S.

Professor of Chemistry in the University of Edinburgh; formerly Lieutenant-Commander in the United States Naval Reserve, acting as Liaison Officer with Allied Services on Chemical Warfare

1938

CASUALTIES IN INITIAL GAS ATTACKS

Gas	*Date*	*Amount Used In Tons*	*Lethal Concentration* *	*Non-fatal injuries*	*Deaths*
Chlorine	Apr. 22, 1915	168	5·6	15,000	5,000
Phosgene	Dec. 19, 1915	88	0·5	1,069	120
Mustard	July 12, 1917	125	0·15	2,490	87

(* mg/litre for 10 minutes exposure unprotected)

between September 15 and November 11, 1918, 2,000,000 rounds of gas shell, containing 4,000 tons of mustard gas, were fired against the advancing British troops; our losses therefrom were 540 killed and 24,363 injured. Gas defence had progressed to the point where it took nearly 8 tons of mustard gas to kill a single man!

The first salvo of gas shells often reaches the trenches before the occupants don their masks, whereas the Londoner will receive ample warning of the approaching danger.

The alarmist and the ultra-pacifist love to quote the fact that one ton of mustard gas is sufficient to kill 45,000,000 people. This would indeed be true if the 45,000,000 people all stood in a line with their tongues out waiting for the drops to be dabbed on, but they are hardly likely to be so obliging. One steam-roller would suffice to flatten out all the inhabitants of London if they lay down in rows in front of it, but nobody panics at the sight of a steam-roller.

11

Ever since the Armistice, three classes of writers have been deluging the long-suffering British public with lurid descriptions of their approaching extermination

These three classes are pure sensationalists, ultra-pacifists and military experts.

12 PANIC PALAVER

perpetrators of such articles may not recognize themselves that what they are writing is almost entirely imaginary, but they do want to get their manuscript accepted for the feature page of the *Daily Drivel* or the *Weekly Wail*. In order to do that, they must pile on the horrors thick, and they certainly do their best

The amount of damage done by such alarmists cannot be calculated, but it is undoubtedly very great.

poison gas has a much greater news value. It is still a new and mysterious form of warfare, it is something which people do not understand, and what they do not understand they can readily be made to fear.

13

The recent film *Things to Come*, in particular, has provided a picture of chemical warfare of the future which shows how simply and rapidly whole populations will be wiped out. Millions of people, perhaps, have been impressed by the authority and reputation of Mr. H. G. Wells into believing that this picture represents the plain truth.

17

Exhibit 'B' is the work of the ultra-pacifist. He abominates war and everything connected with war to such an extent that he paints a highly coloured picture of its horrors, in the most extreme Surrealistic style, with the object of frightening the public to the point where they will relinquish, in the hope of escaping war, even the right of self-defence. His motives may be praiseworthy, but his methods are to be deplored.

Tel. No.: VICtoria 6826

Any communication on the subject of this letter should be addressed to—

THE UNDER SECRETARY OF STATE,
HOME OFFICE (A.R.P. DEPT.),
HORSEFERRY HOUSE,
THORNEY STREET,
LONDON, S.W.1.

and the following number quoted:—
701,602/109

HOME OFFICE,
AIR RAID PRECAUTIONS DEPT.,
HORSEFERRY HOUSE,
THORNEY STREET,
LONDON, S.W.1.

31*st December*, 1937.

SIR,

Experiments in Anti-Gas Protection of Houses

I am directed by the Secretary of State to transmit, for the information of your Council, the annexed Report describing in detail the experiments to which reference was made by the Parliamentary Under Secretary of State in his speech on the second reading of the Air Raid Precautions Bill in the House of Commons on the 16th November.

The experiments were conducted by the Chemical Defence Research Department under the aegis of a special Sub-Committee of the Chemical Defence Committee. That Sub-Committee was composed of eminent experts not in Government employment, and included a number of distinguished University professors and scientists.

I am,
Sir,
Your obedient Servant,
R. R. SCOTT.

The Clerk of the County Council.
The Town Clerk.
The Clerk to the District Council.

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PROTECTION AGAINST GAS

REPORT OF EXPERIMENTS CARRIED OUT BY THE CHEMICAL DEFENCE RESEARCH DEPARTMENT

Handbook No. 1 issued by the Air Raid Precautions Department of the Home Office describes the steps which the public are advised to take in order to protect themselves against the effects of any chemical warfare gases which might be employed by enemy aircraft in time of war.

The gist of these recommendations is:—

First, to go indoors.

Secondly, to arrange for the room into which you go to be made as gas-proof as possible.

Thirdly, to take with you the respirator which will have been issued to you.

Whilst it has never been claimed that any one of these steps by itself will make an individual completely safe, experiments and trials have shown that each of these measures is by itself of considerable value and that when all of them are adopted a very high degree of protection is obtained. An outline is given below of certain typical experiments which have been carried out.

These particular experiments were carried out with four different types of actual war gas. The first four experiments to be described will show the degree of protection that is obtained from each type of gas merely by going indoors and shutting the doors and windows.

As explained in Handbook No. 1*, a chemical warfare gas may be dropped from aircraft either as spray or in bombs. In the former case the liquid drops fall like rain, and it is obvious that by going indoors the public will avoid them. On the other hand, if gas bombs are dropped, people who have gone indoors will avoid being splashed by the chemical in the bomb, and even in an ordinary room they will receive some protection from the gas cloud. The amount of protection obtained in a house which has not been treated in any way can be gathered from the following experiments.

(a) *Protection obtained in a house which has not been treated in any way.*

The house employed was a gamekeeper's cottage with three rooms on the ground floor and three rooms upstairs. It had been unoccupied for about 15 years but was in a reasonable state of repair. It was to a large extent sheltered by belts of

* A.R.P. Handbook No. 1, "Personal Protection against Gas", price 6d. (8d. post free): published by H.M. Stationery Office (see back page).

trees which reduced the strength of the wind in the vicinity of the cottage to about one-eighth of that in the open. In this respect therefore the location of the cottage resembled a house in a town. In one experiment over a ton of actual chlorine gas was released 20 yards from the house so that the wind carried it straight on to the unprotected room. A very strong gas cloud was thus maintained outside the house for about 40 minutes, during which time the gas gradually penetrated to the inside. A fire was burning in the hearth the whole time, and the only measures taken to exclude the gas consisted of closing the doors and windows in the normal way.

Human beings who occupied this unprotected room found that gas penetrated slowly into the room, and after about seven minutes is became necessary for them to put on their respirators. Had these men been outside the house, they would have been compelled to put on their respirators immediately, since otherwise the very intense gas cloud would have caused instantaneous incapacitation and ultimate death.

If the gas, which with its containers weighed about 2½ tons, had been released more quickly, the strength of the gas cloud would have been greater but the time during which the house was enveloped by it would have been correspondingly shorter.

It is important to appreciate properly the severity of this trial. The quantity of gas concentrated on this house could under practical conditions only be obtained by several large bombs dropping very close to the building. The period of exposure to the maximum effects of the gas was also many times longer than would normally be experienced under most practical conditions, since the initial cloud from a gas bomb soon begins to be diluted and dispersed by the action of even quite moderate winds. It is clear that conditions similar to those of the experiment are extremely severe, and are such as would be likely to occur very rarely indeed and to a very small number of houses.

It should also be noted that the cottage used in this experiment had no carpets or other floor coverings. Most of the gas which leaked in came through the spaces between the floor boards, and it is therefore clear that much less would have got into an ordinary room in which there was a carpet, linoleum, or a solid floor.

In another experiment the house was surrounded at a distance of 20 yards by large shallow trays which were filled with mustard gas, the trays being spaced a few yards apart. By this means the vapour given off by the mustard gas was carried on to the house no matter how the direction of the wind varied. As the weather at the time was not very warm, the conditions of the experiment were made more severe by producing a fine spray of mustard gas at a point 10 yards to windward of

the house so that the house was enveloped in the resultant cloud of mustard gas for a period of an hour. The cloud produced in this way was about a hundred times as strong as that caused by the evaporation of the mustard gas from the trays. Animals were placed in an unprotected room in the house and remained there during the spraying period and for a further 20 hours while the house was subjected to the vapour of mustard gas given off from the trays. Observations made upon the animals during the three subsequent days and also post mortem examination showed that none of them was seriously harmed by the mustard gas.

The third type of gas used was tear gas. In this experiment the same cottage was enveloped for an hour in an intense atmosphere of tear gas produced by spraying the gas into the air at a point 10 yards upwind of the house. Men who were stationed 200 yards downwind from the house and in the track of the gas cloud were incapacitated in about a minute, and in some cases in 20 seconds. On the other hand, men who occupied rooms in the house which had received no treatment beyond the closing of the windows and doors found no need to put on their respirators for the first 13 minutes. The tear gas gradually penetrated into these unprotected rooms, although after three-quarters of an hour the strength of the gas inside the house was still very much less than that outside.

In the fourth experiment the cottage was enveloped for 20 minutes in a dense cloud of arsenical smoke. Men occupying an unprotected room of the house found that the arsenical smoke penetrated into the room, but the strength of the cloud inside was much less than that outside. When Civilian respirators were worn in this room, complete protection was obtained. Men who were stationed 200 yards downwind of the house and in the path of the gas cloud were rapidly affected, but when they wore Civilian respirators no effects were felt.

The above four examples clearly demonstrate that, apart from the protection which a house provides against falling airplane spray, some measure of protection is afforded even by an ordinary unprotected room against gas clouds such as are produced by bombs close to the building.

(b) *Protection afforded by a house treated in accordance with Air Raid Precautions Handbook No. 1.*

A brief account will now be given of four further experiments with the same four war gases in order to illustrate the added protection which can be obtained by treating a room in accordance with the instructions given in Air Raid Precautions Handbook No. 1. These experiments were also conducted with the cottage already mentioned. The room selected for treatment was situated on the ground floor on the windward side

of the house so that it was subjected to the full effect of the gas and the wind. It measured about 12 feet square. The Air Raid Precautions instructions for excluding gas were carried out by unskilled men, the official procedure being rigidly followed. As the house was not provided with carpets or other floor covering, it became necessary to seal up the joints between the boards over the whole of the floor of the selected room. This was done by pasting strips of paper along the joints between the floor boards. Some of these strips became displaced by the boots of the men who were inside the room, and an appreciable leakage of gas into the room undoubtedly occurred due to this cause. Two tons of chlorine were released 20 yards from the house, the time of emission being an hour. Animals were placed in the house, some in the " gas protected " room and others in rooms which had received no such treatment. The latter set of animals were killed by the gas which penetrated into the unprotected rooms under these very severe conditions. The animals in the " gas protected " room, however, were unaffected and remained normal, notwithstanding the severity of the trial.

An experiment with mustard gas, similar to that already described, was also carried out after the ground floor room on the windward side of the house had been treated in accordance with the Air Raid Precautions Department's procedure. Animals were placed in the room, which was then subjected to the same exposure of mustard gas spray and vapour as before. At the end of 20 hours the animals were removed and a most thorough examination of them showed no evidence of the effects of the gas at all. Animals placed outside the house during the first hour of the experiment were, of course, very seriously affected. The amount of mustard gas penetrating into the room was also measured by chemical methods and it was found that the amount of gas inside the room was so small that a man could have remained there for the whole 20 hours without its being necessary for him to wear a respirator and without any subsequent ill-effects.

The experiment with tear gas previously described was also performed against the " gas protected " room. A number of men occupied this room and found they were able to remain there without its being necessary for them to put on their respirators at any time during the hours that this very severe experiment lasted.

An experiment with arsenical smoke, similar to that already described, was also carried out against the " gas protected " room. The occupants found that the arsenical smoke penetrated the room to an extent which caused some irritation of the nose and throat and eventually rendered the wearing of respirators desirable to ensure comfort. After putting on the respirator, no

discomfort was felt throughout the remainder of the experiment. Men who left the " gas protected " room wearing their Civilian respirators were able to traverse the densest part of the cloud without discomfort. Under these severe conditions the presence of the arsenical smoke could be detected, but the effects were insignificant.

It is important to appreciate fully the severity of the conditions imposed in the two trials with arsenical smoke. A very high concentration of the irritant smoke was maintained around the house for 20 minutes. Under practical conditions such a high concentration could be produced only by a large and efficiently designed bomb falling close to the building, and then only for a short period. The conditions of the trials were therefore extremely severe and represent a situation which would only rarely be met, and in which only a small number of houses would be involved.

From this second series of experiments it will be seen that treating a room in accordance with the recommendations of the Air Raid Precautions Department does reduce very considerably the amount of gas penetrating into the room, and that a room so treated is correspondingly safer than a room which has received no such treatment.

Indeed, in the case of the experiments with mustard gas and tear gas, the amount of gas which was able to penetrate into the gas protected room was so small that no further measures of protection were necessary.

In the experiment with chlorine, although the amount of gas which entered the treated room was insufficient to injure the animals, human beings who occupied the room during this extremely severe test could smell the gas. They were provided with Civilian respirators, and they found that by putting these respirators on they were completely protected against every trace of gas. Some of these individuals then left the " gas protected " room, passed out of the house, and traversed the lethal cloud of gas which enveloped it. Although they deliberately stood in the densest part of the cloud for some minutes, no trace of the gas passed through their respirators.

Similarly the experiments with arsenical smoke show that although, under the most severe conditions, the cloud may penetrate into the " gas protected " room in sufficient quantity to be detected, or even to cause some irritation, the effects are materially reduced in a room so treated. It is also demonstrated that wearing a Civilian respirator affords complete protection against any smoke which may gain access to the room. The respirator also enabled individuals to pass through an extremely dense cloud of arsenical smoke in complete safety.

The experiments which have been outlined in this statement were purposely designed to represent the most severe conditions likely to be met. The results all combine to show that if the instructions given in Air Raid Precautions Handbook No. 1 are carried out a very high standard of protection is obtained. With regard to the first precaution it has been shown that going indoors and closing the doors and windows affords some measure of protection, even though the room occupied has not been specially prepared. In these circumstances there is ample time to put on the respirator at leisure if this should be necessary. If the second precaution of rendering the room as gas-proof as possible has been carried out, then the occupants will normally be able to remain in complete safety and comfort without further protection. Under the most severe conditions sufficient gas may penetrate such protected rooms to be recognized or even to cause slight irritation. When this occurs the respirator can be put on though in many cases this will be as a matter of convenience and extra precaution rather than real necessity. With regard to the Civilian respirator it has been shown that this will, in conjunction with the above precautions, provide complete safety for any period for which it is likely to be required. It has further been demonstrated that this respirator will enable the wearer to reach a place of safety even if he should for a time be exposed to the most dangerous situation—for example if he is caught out of doors in a gas cloud, or if his gas-protected room becomes damaged and he is compelled to seek shelter elsewhere.

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Manual of Basic Training

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BASIC CHEMICAL WARFARE

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1949

CHAPTER VII

51. COLLECTIVE PROTECTION

Every individual can rely on his respirator for his own protection against war gas, and this is his primary defence, but the protection which is afforded against vapour, by buildings in sound condition, is of considerable value and against liquid and spray is complete.

HOME OFFICE

SCIENTIFIC INTELLIGENCE OFFICERS' OPERATIONAL NOTES

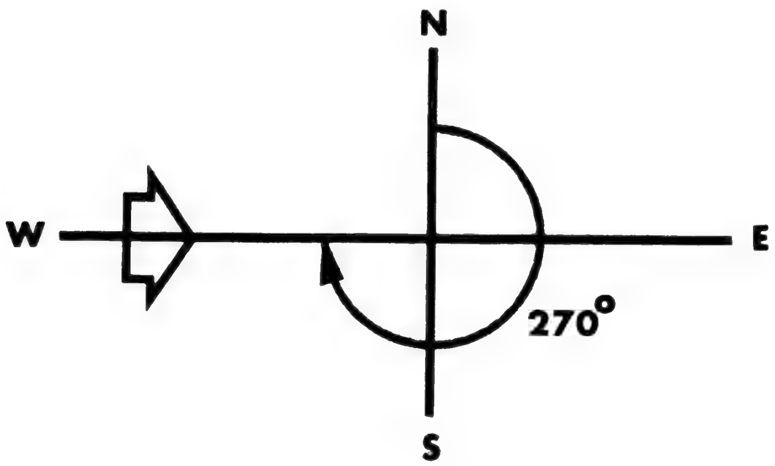
RESTRICTED

The information given in this document is not to be communicated, either directly or indirectly, to the Press or to any person not authorised to receive it.

Mechanism of fallout

Definitions

Wind direction is the direction from which the wind blows, and is given in degrees measured clockwise from north. E.g. A 270° wind blows from the west.



Wind speed is actually measured in knots, but the unit of speed usually used by the SIO is the mile per hour (mph).

1 knot = 1 nautical mile per hour

1 nautical mile = 6080 feet

1 knot = 1.15 mph

N.B. In meteorological forecasts received by the SIO wind speeds will normally be in mph. If a forecast is mistakenly transmitted in knots, then the SIO should transform, using the above relationship. In approximate calculations the difference between a knot and a mile per hour may be neglected.

Winds changing direction with time

(a) If a wind turns clockwise it is said to be veering.

(b) If a wind turns anticlockwise it is said to be backing.

A forecast concerns meteorological data only.

A prediction indicates where fallout may go. It is based on a forecast and on bomb data.

A micron (μ) is one millionth of a metre.

1000 microns = 1 millimetre.

Useful wind data

The following data applies to the 0-60,000, 0-70,000 and 0-80,000 feet mean vector winds.

(a) Variation with speed

Probabilities of occurrence of speeds (all directions)

Speed range (mph)	0-7	7-18	18-35	35+
Percentage probability	4	17	36	43

(b) Variation with direction

Probabilities of directions occurring in 60° sectors (all speeds)

Wind direction (degrees)	0-60	60-120	120-180	180-240	240-300	300-360
Percentage probability	7	4	5	17	41	26

(c) Angular wind shear

This is defined for the present purpose as the angle which includes the directions of all the mean vector winds up to the 0-90,000 feet one, excluding the surface wind. This angle will give a very crude idea of the amount of lateral spreading which might occur in the fallout pattern.

Percentage probability of occurrence of angular shear

Angular shear (degrees)	Mean vector wind speed (mph)				Total
	0 - 7	7 - 18	18 - 35	35 +	
0-15	0	$2\frac{1}{2}$	$9\frac{1}{2}$	21	33
15-30	$\frac{1}{2}$	$3\frac{1}{2}$	13	11	28
30-75	$\frac{1}{2}$	7	$10\frac{1}{2}$	10	28
75 +	3	4	3	1	11
Total	4	17	36	43	100

Mode of decay

Any single radioisotope decays according to an exponential law $N_t = N_o e^{-\lambda t}$, where N_o and N_t are the number of atoms present initially and at time t. λ is a decay constant and can be shown to equal 0.693/T, where T is the half-life of the isotope, i.e. if the activity was originally, say, 8 units, then it will have decayed to 4 units after time T, 2 units after time 2T, 1 unit after time 3T, etc.

Fission products from a nuclear explosion are a mixture of over 200 different radioisotopes with half-lives varying from fractions of a second to many thousands of years. Many of them, moreover, are not produced immediately but are the result of the decay of other nuclides. In addition, the mixture may contain some activity due to neutron activation of the bomb components resulting in the formation of neptunium 239. The decay of this mixture is not exponential and thus cannot be described by a half-life. From nuclear weapons trials it has been found for the first 100 days to follow approximately the $t^{-1.2}$ power law, i.e. $R_t = R_1 t^{-1.2}$, where R_1 and R_t are the dose-rates at 1 hour and t hours after detonation

Factors upsetting normal decay

Probable causes of deviation from the $t^{-1.2}$ decay law are:-

(a) fractionation
(b) neutron activation of soil elements
(c) weathering
(d) rigging or salting of weapons

Fractionation

This is a complex condensation process and is by no means fully understood. Its effect is to give the close-in FO a different composition and hence a different decay from the more distant FO downwind. For example, close-in FO has been found to contain less strontium 90.

Two likely causes of fractionation are:-

(a) as the fireball cools the nuclides with the higher boiling points condense first and do so while the larger particles forming the close-in FO are still present in the cloud. The more volatile nuclides condense later when the larger particles have left the cloud and so tend to contaminate the lighter particles which are carried further downwind.

(b) certain of the fission products are inherently gaseous (e.g. krypton) or have gaseous precursors (e.g. caesium 137). The heavier particles fall out before these nuclides have decayed to non-gaseous daughters capable of condensing on to them. Close-in FO is therefore deficient in these elements. Conversely the smaller particles forming the more distant FO are enriched in them.

Neutron activation of soil elements

For FO to be produced on a substantial scale, the explosion must take place on or near the ground, in which case the radioactivity from the fission products and the bomb materials is supplemented by neutron-induced activity from certain elements in the soil. For the 50% fission weapon this extra activity is small but may be appreciable for the so-called "clean" bomb where possibly only 10% of the total energy is from fission. The number of spare neutrons is doubled and the fission product activity reduced by a factor of 5. Under these circumstances induced activity can become a substantial proportion of the whole. Calculations made on typical UK soils show that the elements most likely to contribute to this activity are sodium and manganese. Under neutron activation these form the gamma emitters sodium 24 and manganese 56. Sodium and manganese are present in soils in varying amounts according to the locality. Sodium, for example, is more abundant in the rock-salt areas of Cheshire and in regions of igneous rock formation. Manganese is fairly uniformly distributed but usually only in small amounts.

If a large quantity of a particular isotope such as sodium 24 is added to a fission product mixture obeying the $t^{-1.2}$ law, the effect is to increase the dose-rate by an amount varying with time. It can be shown that the isotope exerts its maximum proportional effect at a time equal to 1.73 times its half-life. For sodium 24 and manganese 56 the details are:-

Isotope	Half-life (hours)	Time of maximum proportional effect (hours)
Na24	15	26
Mn56	$2\frac{1}{2}$	$4\frac{1}{2}$

For a 10% fission bomb the sodium 24 contribution to the total DR at H + 26 hours could be over 80% for some bomb designs and soil constitutions; the manganese 56 contribution at H + $4\frac{1}{2}$ hours could be over 10%.

Notes on BW and CW

General

Toxicological warfare can consist either of a tactical attack with chemical weapons producing an immediate incapacitating effect, or of a strategic attack with biological weapons which have a delayed effect.

The new Civilian Respirator (C7), with pneumatic tube face fitting which is comfortable for long periods of wearing, affords excellent protection against BW and CW attacks.

BW

In attacks on populations, since the airborne hazard is the main one, only agents of high infectivity and high virulence (i.e. a small number of organisms required to produce infection and cause severe illness), combined with viability for many hours in the atmosphere, are likely to prove effective.

Some representative pathogenic micro-organisms

Bacterial	Anthrax	(lethal, very persistent spores but relatively low infectivity)
	Brucellosis	(incapacitating)
	Tularaemia	(incapacitating or lethal)
	* Rickettsial	Q fever (like typhus)
	* Viruses	Encephalomyelitis (brain fever)
		Smallpox (epidemic)

Personal protection

Respirators and discardible covers for head and body may be used. Extreme personal cleanliness is necessary. Total dosage can be reduced very considerably in a closed room in a house by sealing window cracks and door gaps before the arrival of contamination and ventilating the room fully as soon as it has passed.

Decontamination

Where appropriate the following measures may be taken:-

(a) weathering for a few days will destroy most bacterial agents other than anthrax spores
(b) use of bleach solution
(c) scattering petrol and firing it on open contaminated ground.

CW

Mustard gas and anticholinesterase agents (persistent and non-persistent nerve gases) are the CW agents most likely to be encountered in a tactical battle.

Building/ Vehicle Type	Air Exchange Rate (ACH)	Time Building Is Exposed (hr.)	Time of Occupancy from Cloud Arrival (hr.)	Shielding Factor
Residential Building (Windows Closed)[1]	0.53	0.25	0.25	15.8
	0.08-3.24	0.25	0.25	100.7-3.2
Residential Building (Windows Open)[1]	6.4	0.25	0.25	2.0
Nonresidential Building[1]	1.285	0.25	0.25	6.9
	0.3-4.1	0.25	0.25	27.3-2.7
Vehicle[1]	36	0.25	0.25	1.1
Mass-Transit Vehicle[1]	1.8-5.6	0.25	0.25	5.1-2.2
Stationary Automobile[2]:				
Windows Closed/No Ventilation	1.0-3.0	0.25	0.25	8.7-3.4
Windows Closed/Fan On Recirculation	1.8-3.7	0.25	0.25	5.1-2.9
Windows Open/No Ventilation	13.3-26.1	0.25	0.25	1.4-1.2
Windows Open/Fan On Fresh Air	36.2-47.5	0.25	0.25	1.1

1 Ted Johnson, A Guide to Selected Algorithms, Distributions, and Databases used in Exposure Models Developed by the Office of Air Quality Planning and Standards (Chapel Hill, NC: TRJ Environmental, Inc., 22 May 2002), http://www.epa.gov/ttn/fera/data/human/report052202.pdf. Accessed 8 January 2008.

2 J. H. Park et al., "Measurement of Air Exchange Rate of Stationary Vehicles and Estimation of In-Vehicle Exposure," Journal of Exposure Analysis & Environmental Epidemiology 8, no. 1 (January–March 1998):65-78.

ORNL/TM-10423

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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Technical Options for Protecting Civilians from Toxic Vapors and Gases

C. V. Chester

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Prepared for
Office of Program Manager
for
CHEMICAL MUNITIONS
Aberdeen Proving Grounds, Maryland

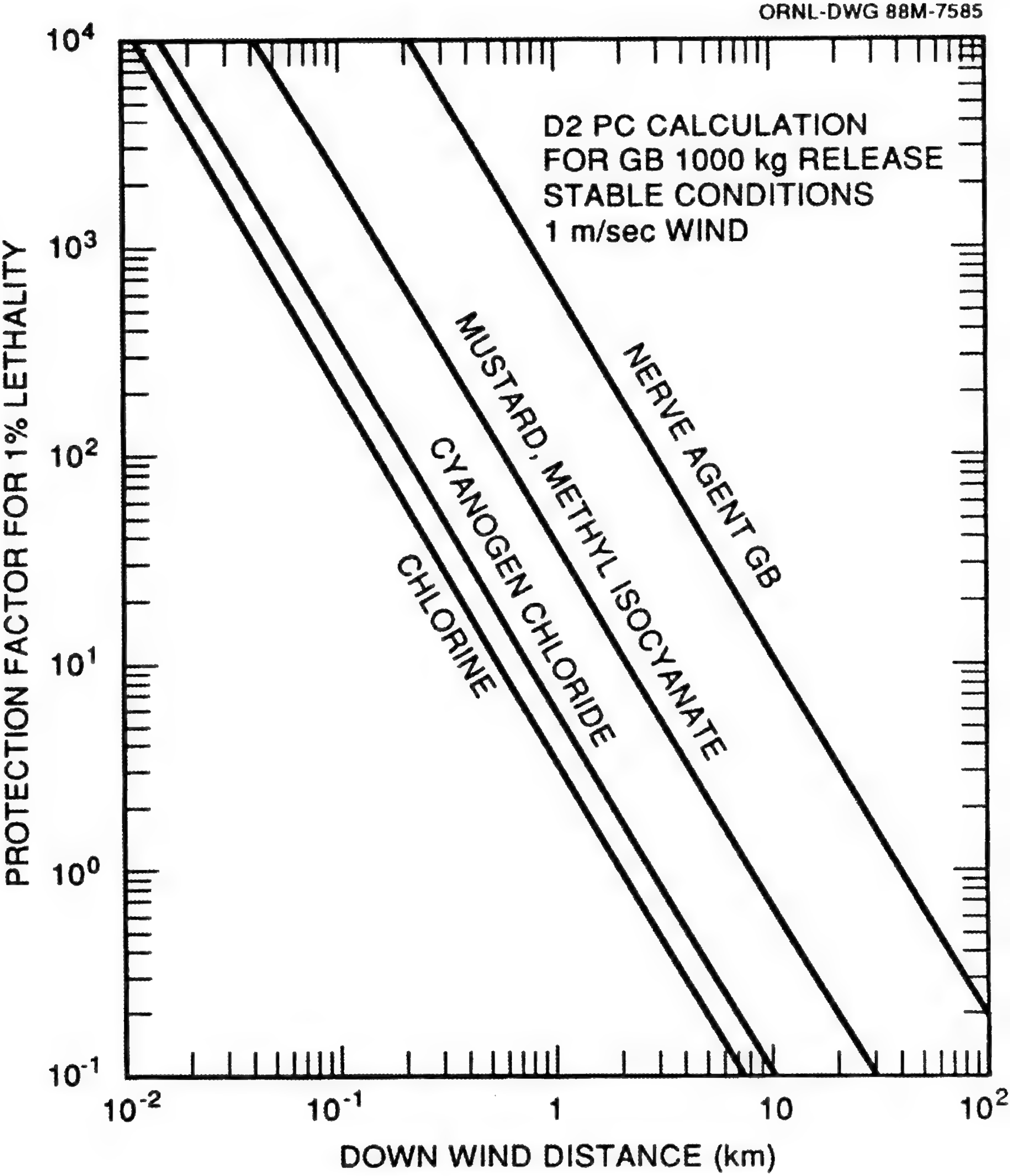

Fig. 1 Dose vs Downwind Distance for Some Very Toxic Gases

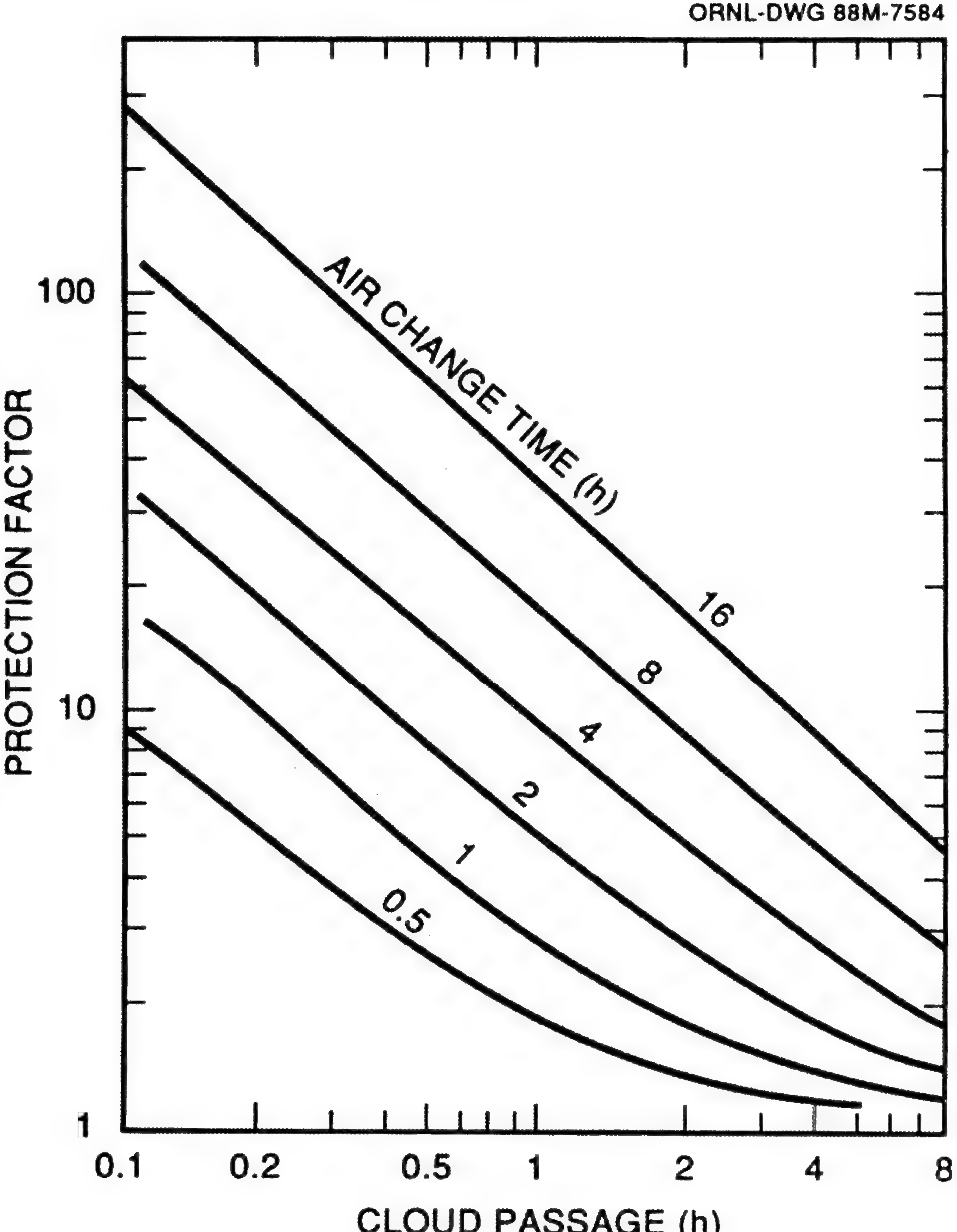

Fig. 2 Protection Factor of Leaky Enclosures

ORNL-DWG 88M-7581

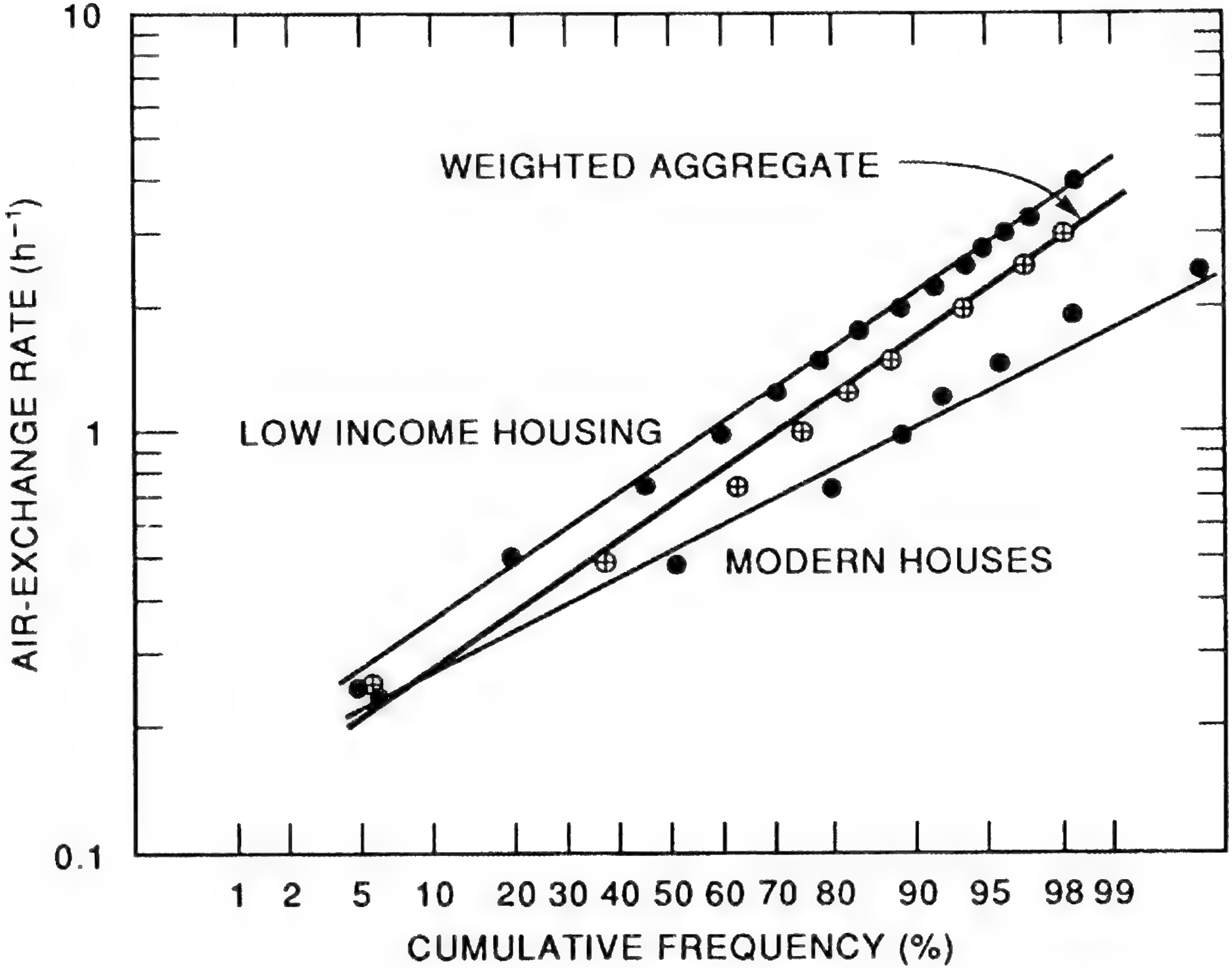

Fig. 3 Infiltration Rates of American Residences

ORNL/TM-2001/154

Energy Division

Will Duct Tape and Plastic Really Work? Issues Related To Expedient Shelter-In-Place

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Chemical Stockpile Emergency Preparedness Program

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Although vapors, aerosols, and liquids cannot permeate glass windows or door panes, the amount of possible air filtration through the seals of the panes into frames could be significant, especially if frames are wood or other substance subject to expansion and contraction. To adequately seal the frames with tape could be difficult or impractical. For this reason, it has been suggested that pieces of heavy plastic sheeting larger than the window be used to cover the entire window, including the inside framing, and sealed in place with duct or other appropriate adhesive tape applied to the surrounding wall.

Another possible strategy would be to use shrink-wrap plastic often used in weatherization efforts in older houses. Shrink-wrap commonly comes in a 6 mil (0.006-in.) thickness and is adhered around the frame with double-faced tape and then heated with a hair dryer to achieve a tight fit. This would likely be more expensive than plastic sheeting and would require greater time and effort to install. Because double-faced tape has not been challenged with chemical warfare agents, another option is to use duct tape to adhere shrink-wrap to the walls. Currently, we do not recommend using shrink-wrap plastics because of the lack of information on its suitability and performance.

3. WHY WERE THESE MATERIALS CHOSEN?

Duct tape and plastic sheeting (polyethylene) were chosen because of their ability to effectively reduce infiltration and for their resistance to permeation from chemical warfare agents.

3.1 DUCT TAPE PERMEABILITY

Work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical resistant fabrics and duct tape of 10 mil (0.01-in.) thickness. The materials were subject to liquid challenges by the simulants DIMP (a GB simulant), DMMP (a VX simulant), MAL (an organoposphorous pesticide), and DBS (a mustard simulant). The authors note that simulants should behave similarly to live agents in permeating the materials; they also note that this should be confirmed with the unitary agents. The study concluded that "duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3.2 PLASTIC SHEETING PERMEABILITY

Tests of the permeability of plastic sheeting (polyethylene) challenged with live chemical warfare agents were conducted at the Chemical Defense Establishment in Porton Down, England in 1970 (NATO 1983, p. 133). Agents tested included H and VX, but not GB. Four types of polyethylene of varying thickness were tested: 2.5, 4, 10 and 20 mil (0.0025, 0.004 in., 0.01 in., and 0.02 in.). The results of these tests are shown in Table 1.

Table 1: Permeability of plastic sheeting to liquid agent

	Breakthrough time (h)	
Thickness	VX	H
0.0025	3	0.3
0.004	7	0.4
0.01	30	2
0.02	48	7

Source: NATO 1983, p. 136.

The data shows that at thickness of 10 mil or greater, the plastic sheeting provided a good barrier for withstanding liquid agent challenges, offering better protection against VX than for H. Because the greatest challenge is from a liquid agent, the time to permeate the sheeting will be longer for aerosols and still longer for vapors, but the exact relationship is unknown due to a lack of test data.

NATO Civil Defense Committee 1983. *NATO Handbook on Standards and Rules for the Protection of the Civil Population Against Chemical Toxic Agents*, AC/23-D/680, 2nd rev.

Pal, T., G.Griffin, G. Miller, A. Watson, M. Doherty, and T. Vo-Dinh. 1993. "Permeation Measurements of Chemical Agent Simulants Through Protective Clothing Materials," *J. Haz. Mat.* **33**:123-141.

THE PROTECTION OF THE PUBLIC FROM AERIAL ATTACK

Being

A CRITICAL EXAMINATION OF THE RECOMMENDATIONS PUT FORWARD BY THE AIR RAID PRECAUTIONS DEPARTMENT OF THE HOME OFFICE

by

THE CAMBRIDGE SCIENTISTS' ANTI-WAR GROUP

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1937

the time taken for the gas to leak out to half its original value was measured in four rooms—the basement of a shop, the dining-room of a semi-detached house, the sitting-room of a Council house and the bathroom of a modern villa. As stated above the leakage half-times for these rooms were $2\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$ and $9\frac{1}{4}$ hours respectively. The reason for the last room being so much better than all the others is that it has steel-frame windows which were sealed with plasticine, painted and tiled walls, and a concrete floor covered with cork tiles.

Note: even a 1 mile wide gas cloud passes in 6 min in 10 miles/hr wind (hence good protection) 41

This property of drifting with the wind is of some importance, for it means that the gas will not remain for long periods in any one place except on still days.

Now it may be objected that, although the "gas-proof" room is not hermetically sealed, it will nevertheless protect the occupants for the two or three hours necessary in case of an attack by a choking gas.

We assume that the gas blows away so quickly that every 10 minutes its concentration is halved. In Engelhard's experiments it took 10 minutes to liberate the gas from its cylinders, so that this assumption is reasonable. Then a person occupying a good "gas-proof" room, the leakage half-time of which (defined on p. 18) is 3 hours, would have breathed a lethal dose of phosgene in 2 hours.

Gas-schutz und Luftschutz, 4, 174, 1934

Complete lies: bombs are dropped, not cylinders. Engelhard's 1934 article in the Nazi controlled "Gas protection and air protection" journal is enemy propaganda; the Nazis kept the facts secret

As, however, our experiments on the "gas-proof" room illustrate quite clearly that the ordinary dwelling-house is quite incapable of affording protection, it probably will not matter much what a civil population does under a gas and incendiary attack. Nor is it profitable to argue whether the gas or incendiary bomb is the more devastating, as it is necessary to contemplate an air attack in which both will be employed, with a sprinkling of high explosive bombs, which will considerably heighten the "psychological effect." This is the type of attack which people in large towns must expect if war breaks out; our task in this section is to discuss the proposals of the Home Office for dealing with incendiary bombs, remembering that whoever deals with them will require, almost certainly, simultaneous protection against gas. PROVED WRONG!

 PROPAGANDA

extreme lightness and cheapness of the incendiary bomb must be borne in mind. Mr. Noel-Baker cites the case of a single aeroplane carrying a load of less than a ton of bombs which succeeded in starting three hundred fires, and if we take a specimen raid of nine bombers, each carrying a thousand "kilo" bombs, nine thousand of these could be dropped on an area of two square miles. If very generous allowances are made for failures to function and for bombs falling on non-inflammable sites, in an urban area one fifth at least of these bombs should cause fires. This makes one thousand eight hundred fires. The danger of fire spreading over several blocks of buildings as in the San Francisco (1906) and Tokyo (1933) earthquakes, making the centre of the conflagration quite unapproachable by fire brigades is obvious.

To summarise this section, we reach the conclusion:

(*a*) That for individuals the cost of making buildings impenetrable to incendiary bombs is prohibitive.

(*b*) That, bearing in mind the probability of combined incendiary and gas attack, the civilian population will have considerable difficulty in extinguishing fires caused by incendiary bombs in private houses, unless assisted by experts. ← WRONG!

(*c*) That the fires caused by a raid such as is outlined above would very likely be impossible to deal with, even with the improved fire brigade organisation envisaged by the Home Office, because of the probable amalgamation of separate outbreaks into a vast conflagration.

FM 3-10

DEPARTMENT OF THE ARMY FIELD MANUAL

CHEMICAL AND BIOLOGICAL WEAPONS EMPLOYMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

FEBRUARY 1962

Line	Munition	Agent	Delivery system	User	5 Employment data (a) Range (1) (Meters) Maximum	(a) Range (2) (Meters) Minimum	(b) Error	(c) Fuze (Capability)
	1	2	3	4	5			
1	Shell, M2A1	HD	4.2-inch Mortar	US ARMY USMC	3,930	180	←Obtain from delivery unit or appropriate firing tables→	M8PD
2	Shell, M360	GB	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11,140	862		M508PD
3	Shell, M60	HD	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11,140			M51A5PD
4	Shell, M121	GB	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14,950			M508PD
5	Shell, M110	HD	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14,950			M51A5PD
6	Shell, T__(M121)	VX	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14,950			T76E6VT [1]
7	Shell, M122	GB	155-mm Gun, M2, M53	USMC	23,500			M508PD
8	Shell, M104	HD	155-mm Gun, M2, M53	USMC				M51A5PD
9	Shell, Gas, 175-mm	GB	M107 Gun (SP)	US ARMY	31,500	180		
10	Shell, Gas, 175-mm	VX	M107 Gun (SP)	US ARMY	31,500	180		VT-M514A1
11	Shell, T174	GB	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC	16,930			M51A5PD
12	Shell, T174	VX	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC.	16,930			T2061VT
13	Rocket, M55, 115-mm (BOLT)	GB	Launcher, M91	US ARMY USMC.	10,970	2,740		M417PD
14	Rocket, M55, 115-mm (BOLT)	VX	Launcher, M91	US ARMY USMC.	10,970	2,740		T2061VT
15	Warhead, M79, 762-mm (HONEST JOHN).	GB	Rocket, M31A1C Launcher, M386.	US ARMY USMC.	24,960	8,500		T2075 Mech Time
16	Warhead, E19R2, 762-mm (HONEST JOHN).	GB	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
17	Warhead, E19R2, 762-mm (HONEST JOHN).	VX	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
18	Warhead, E20, 318-mm (LITTLE JOHN).	GB	Rocket, XM51 Launcher, XM80.	US ARMY USMC.	18,290	3,200 [1]		T2075 Mech Time
19	Warhead, E21, (SERGEANT)	GB	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
20	Warhead, E21, (SERGEANT)	VX	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
21	Bomb, M34A1, 1000-lb, Cluster	GB	Fighter, Bomber	USAF	Range of Aircraft.		←Obtain from delivery unit→	M152E3 Mech Time
22	Bomb, MC-1, 750-lb	GB	Fighter, Bomber	USAF	Range of Aircraft.			M905BD
23	Projectile, 5"/38, MK53, MOD O	GB	5-inch Gun	US NAVY	16,450			MK29MOD3PD
24	Projectile, 5"/54, MK54, MOD O	GB	5-inch Gun	US NAVY	19,200			MK30MOD3PD
25	Warhead, Rocket, 5" MK40, MOD O.	GB	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
26	Warhead, Rocket, 5", MK40, MOD O.	HD	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
27	Bomb, MK94, MOD O	GB	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M103A1ND M195 BD (IMPACT).
28	Bomb, M70A1	HD	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M158ND (IMPACT).
29	Mine, Land, Chemical, M23	VX	N/A	US ARMY	N/A	N/A	N/A	
30	Mine, Land, Chemical, One-Gallon.	HD	N/A	US ARMY	N/A	N/A	N/A	

See notes at end of figure.

Figure 5. Chemical munitions and delivery systems.

5 Employment data—Continued						6 Functioning and physical characteristics of CML munitions				
(d) Time for delivery		(e)	(f)	(g)	(h)	(a)	(b)	(c)	(d)	(e)
(1) Preplanned	(2) Target of opportunity	Organization	Rate of fire per weapon	Height of burst	Diameter (meters) of impact area (single rd) [2]	Weight of munition (kg)	Weight of agent (kg)	Effective weight of agent (kg) [3]	Functioning efficiency of munition (percent)	Agent dissemination efficiency
----	----	6 Mort/Plt 8 Mort/Btry	30 Rds/2 min 105 Rds/15 min	GND	16	10.8	2.72	----	99	
----	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	27	16.1	.739	----	99	
----	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	11	15.2	1.22	----	99	
----	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	49	45.9	2.95	----	99	
----	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	20	42.0	4.4	----	99	
----	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	20m [1]	----	45.9	2.95	----	99	
----	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	49	45.9	2.95	----	99	
----	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	22	43.0	5.31	----	----	
		4 Gun/Btry	----	GND	----	66.8	6.68	----	----	
----		4 Gun/Btry	----	GND	----	66.8	6.04	----	----	
----	½–6 hr	4 How/Btry	6 Rds/4 min 10 Rds/10 min	GND	76	97.0	7.12	----	99	
----	½–6 hr	4 How/Btry	6 Rds/4 min. 10 Rds/10 min.	20m [1]	----	97.0	7.12	----	99	
----	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	GND	46	26.4	4.80	----	99	
----	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	20m [1]	----	26.2	4.54	----	99	
----	15 min	2 Lchr/Bn	2/Hr	Variable	Variable	737	177.5	104.8	95	62 percent.
----	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210	171	95	86 percent.
----	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210			
----	15 min	4 Lchr/Btry	2/Hr	Variable	Variable	119	30			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
----	15 min +flight time.	----	2–6/Ftr 4–18/Bmbr.	Variable	170	513	89.6	----	90	
----	15 min +flight time.	----	2–6/Ftr. 4–27/Bmbr.	GND	127	322	99.9			
----	----	----	----	GND	35	25.1	1.47			
----	----	----	----	GND	40	29.1	2.02			
----	----	----	48 Rkt/Lchr/ 1 min	GND	49	22.9	2.18			
----	----	----	48 Rkt/Lchr/ 1 min	GND	----	----	----			
----	----	----	----	GND	90	222	49.8			
----	----	----	----	GND	29	58.0	272			
----	----	----	----	----	----	10.50	5.23			
----	----	----	----	----	----	5.45	4.50			

[1] Estimated.

[2] Instantaneous agent area coverage 30 seconds after detonation.

[3] Values are the product of values given in columns 6(*b*), 6(*d*), and 6(*e*). Since values for 6(*e*) are not available, values for 6 (*c*)cannot be computed at this time.

Figure 5.—Continued

626007 O—62——2

Agent—GB.
Wind speed—5 knots (approx 9 km/hr).
Temperature gradient—inversion.
Temperature—60° F. (15.5° C.).
Terrain—open, level, scattered vegetation.
Precipitation—none.
Time limitations on the delivery of agent on target—4 minutes or less.
Casualty level desired—20 percent.

Find: Whether or not the mission can be fired with a 105-mm howitzer battery.

Solution:

(*a*) Using figure 11, convert 20 percent casualties among protected personnel to the corresponding casualty level among unprotected personnel. This is 80 percent.

(*b*) Using the "GB (over 30-sec attack)" column of figure 12, determine the total effects components to be 3.21 as follows:

Inversion	1.09
Wind speed, 9 km/hr	1.00
Temperature, 60° F. (15.5° C.)	.12
Open terrain	.30
No precipitation	.70
	3.21

(*c*) Using figure 13, place a hairline between 80 percent on the percent casualties scale and 12 hectares on the target area scale. On the point of intersection on the reference line, pivot the hairline until it intersects 3.21 on the effects components scale. On the munitions expenditure scale, read 12 as the number of 155-mm equivalents required.

(*d*) To find the number of 105-mm rounds required to fire the mission, multiply 12 by a factor of four (obtain this factor from figure 8); the product is 48 rounds.

(*e*) From figure 9, it is evident that one battery of six howitzers can easily fire the mission if no shift of fires is required. Since the target is twice as large as the dispersion pattern of a 105-mm battery (par. 31*c*(3)(*c*) and 41*d*), a shift of fires should be made. Figure 9 gives a time of 30 seconds for shifting of fires. On this basis the battery could fire twenty-four rounds on half the target in a little less than 30 seconds, take 30 seconds to shift fires, and have ample time to deliver the remaining twenty-four rounds on the other half of the target. The firing should be completed in less than 2 minutes.

Munition	Munition expressed in terms of 155-mm chemical equivalents		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	0. 25	--------	0. 28
8-inch Shell	2. 40	2. 17	--------
4.2-inch Mortar Shell	--------	--------	. 62
175-mm Shell	2. 1	2. 1	--------
M55 Rocket	1. 6	1. 6	--------
M79 Warhead—HONEST JOHN	60	--------	--------
E19R2 Warhead—HONEST JOHN	71	71	--------
LITTLE JOHN	10	10	--------
SERGEANT	65	65	--------
M34A1 1000-lb Cluster	30	--------	--------
MC1 750-lb Bomb	35	--------	--------
5″/38 Gas Projectile (Navy)	. 50	--------	--------
5″/54 Gas Projectile (Navy)	. 68	--------	--------
5″ Gas Rocket (Navy)	. 74	--------	--------
500-lb Gas Bomb	17	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	6. 2

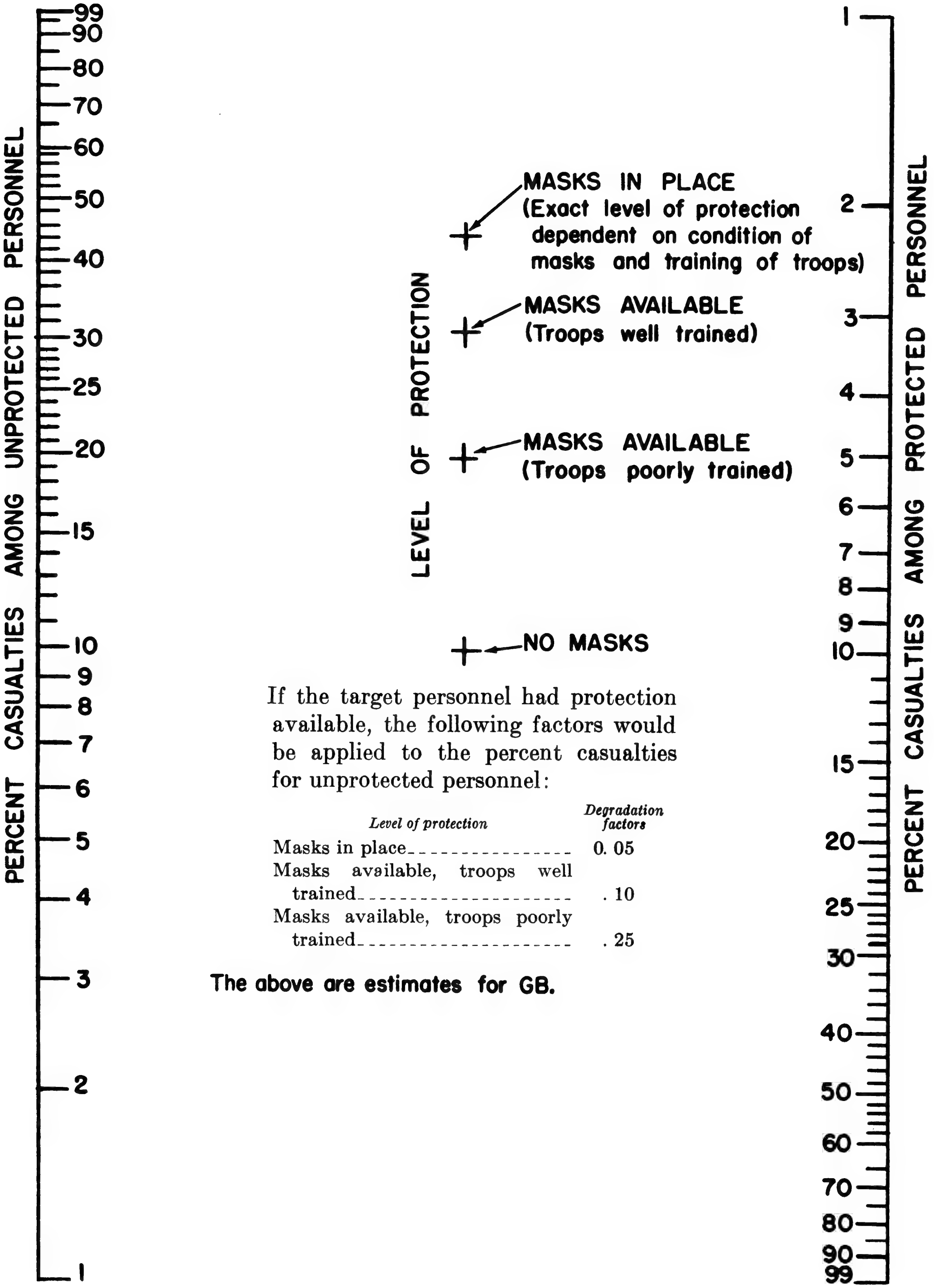
Figure 7. Munitions expressed in terms of 155-mm chemical equivalents. (The figures given are an estimate of the number of 155-mm howitzer rounds required to give the same effect as one round of the specified munition. Dissemination efficiency has not been considered.)

Munition	Conversion factor		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	4	--------	3. 6
8-inch Shell	0. 41	0. 45	--------
4.2-inch Mortar Shell	--------	--------	1. 61
175-mm Shell	. 48	. 48	--------
M55 Rocket	. 61	. 61	--------
M79 Warhead—HONEST JOHN	. 017	--------	--------
E19R2 Warhead—HONEST JOHN	. 014	. 014	--------
LITTLE JOHN	. 098	. 098	--------
SERGEANT	. 016	. 016	--------
M34A1 1000-lb Cluster	. 033	--------	--------
MC1 750-lb Bomb	. 029	--------	--------
5″/38 Gas Projectile (Navy)	2. 00	--------	--------
5″/54 Gas Projectile (Navy)	1. 46	--------	--------
5″ Gas Rocket (Navy)	1. 35	--------	--------
500-lb Gas Bomb	. 059	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	. 164

Figure 8. Conversion factors for converting 155-mm munitions to other munitions.

Weapon	Maximum rate (rounds)	Rates of fire for chemical fire missions without shifting or relaying of the piece (rounds)					Estimated time to shift fires
	30 sec	1 min	2 min	4 min	10 min	15 min	
105-mm Howitzer	6	10	14	18	40	60	30 sec
155-mm Howitzer	3	5	7	12	30	40	30 sec
155-mm Gun	2	4	6	8	12	18	60 sec
8-inch Howitzer	1	2	3	6	10	15	60 sec
4.2-inch Mortar	10	16	30 (max)	50	80	105	30 sec
M91 Launcher (M55 Rocket)	45 (15 sec)	Launcher must relocate after firing each ripple.					

Figure 9. Approximate rates of fire for division cannon artillery, mortars, and multiple rockets firing chemical rounds. (Rates of fire for other weapons are given in figure 5.)



If the target personnel had protection available, the following factors would be applied to the percent casualties for unprotected personnel:

Level of protection	*Degradation factors*
Masks in place	0.05
Masks available, troops well trained	.10
Masks available, troops poorly trained	.25

The above are estimates for GB.

Figure 11. Nomogram for conversion of percent GB casualties for protection of personnel in the target area.

Meteorological and terrain conditions	Effects components			
	GB [2] (surprise attack)	GB (over 30-sec attack)	VX	HD
1. *Temperature Gradient*				
Inversion	0. 67	1. 09	1. 89	0. 69
Neutral	. 57	. 69	1. 89	. 54
Lapse	. 30	. 09	1. 89	. 32
2. *Wind Speed (km/hr)*				
0 to 5	. 20	1. 30	0	. 87
6 to 10	. 50	1. 00	0	. 70
11 to 16	. 70	. 70	0	. 60
17 to 26	. 55	. 30	0	. 48
27 to 52	. 30	0	0	0
3. *Temperature* (° *F.*)				
a. 0 to 39 (−18° to 4° C.)	0	0	0	----------
40 to 79 (5° to 26° C.)	. 12	. 12	0	----------
80 and up (27° C. and up)	. 23	. 23	0	----------
b. 30 to 49 (−1° to 9° C.)	----------	----------	0	0
50 to 69 (10° to 21° C.)	----------	----------	0	. 70
70 and up (22° C. and up)	----------	----------	0	1. 00
4. *Terrain*				
Open, level, scattered vegetation	. 30	. 30	0	. 30
Rugged, mountainous	0	[1] 0	[1] 0	[1] 0
5. *Precipitation*				
None	. 70	. 70	. 70	0
Moderate rain	0	[1] 0	[1] 0	[1] 0

[1] Estimated.
[2] Tentative figures not yet verified.

Figure 12. Effects components.

Note: paragraph 105 on page 82 states that the "safe entry times" after bio attacks are:

NU (Venezuelan equine encephalitis virus),
AB (bovine brucellosis), and
UL (tularemia): 2 hrs sun or 8 hrs cloudy
OU (Q fever): 2 hrs sun or 18 hrs cloudy

Cloudy conditions also apply to nighttime

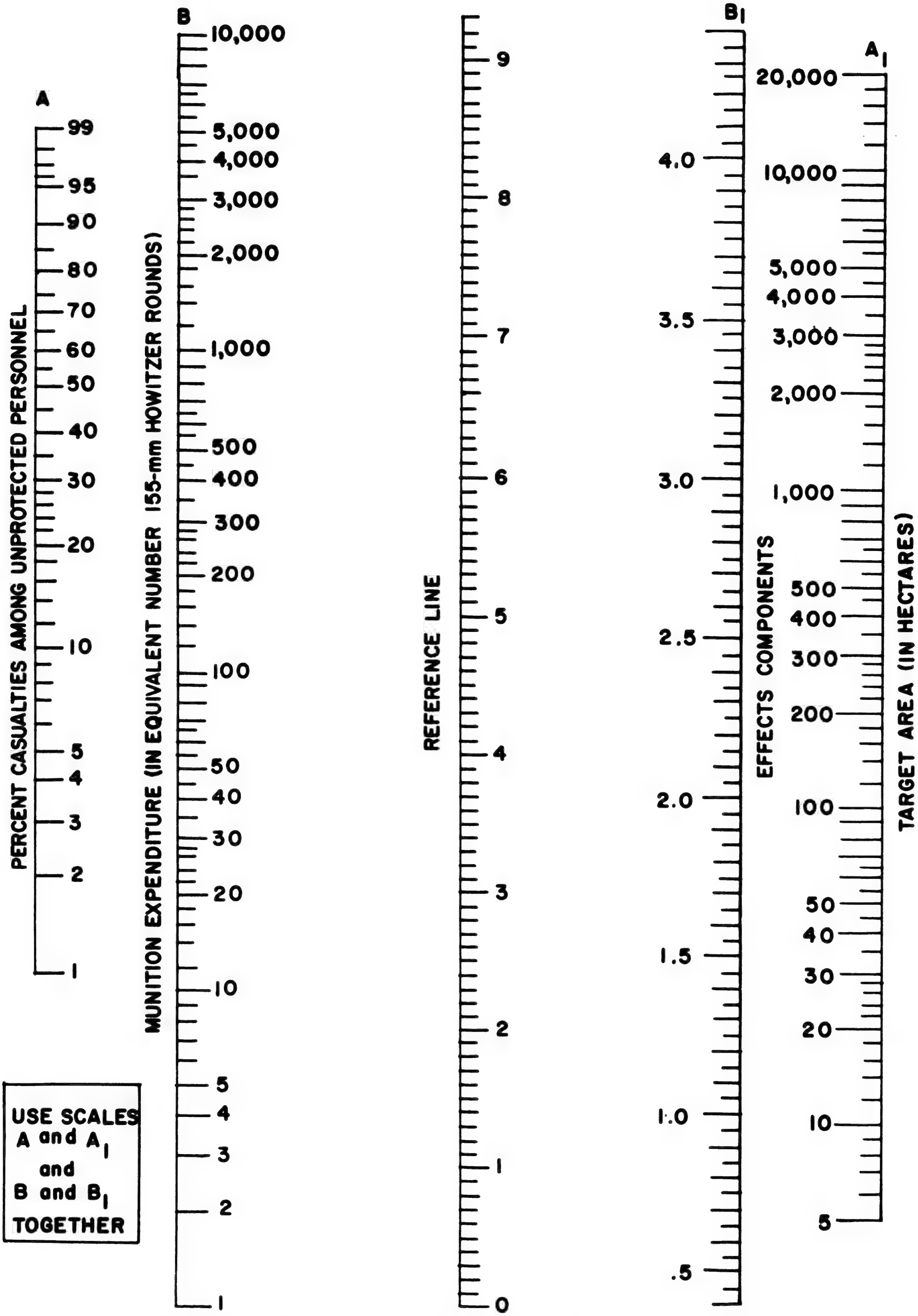


Figure 13. Target area, casualty level, munitions requirement nomogram.

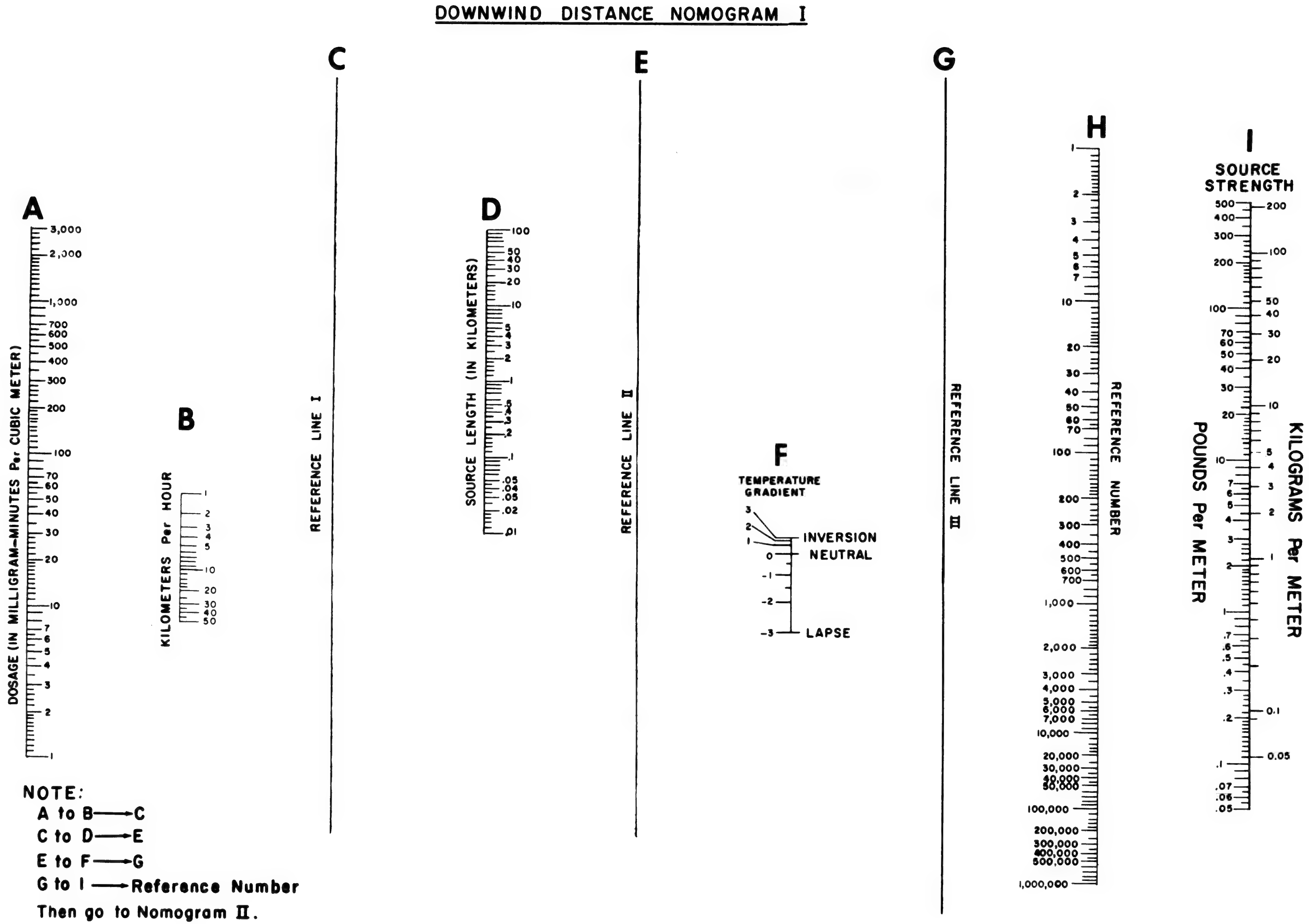


Figure 14. Downwind distance nomogram I.

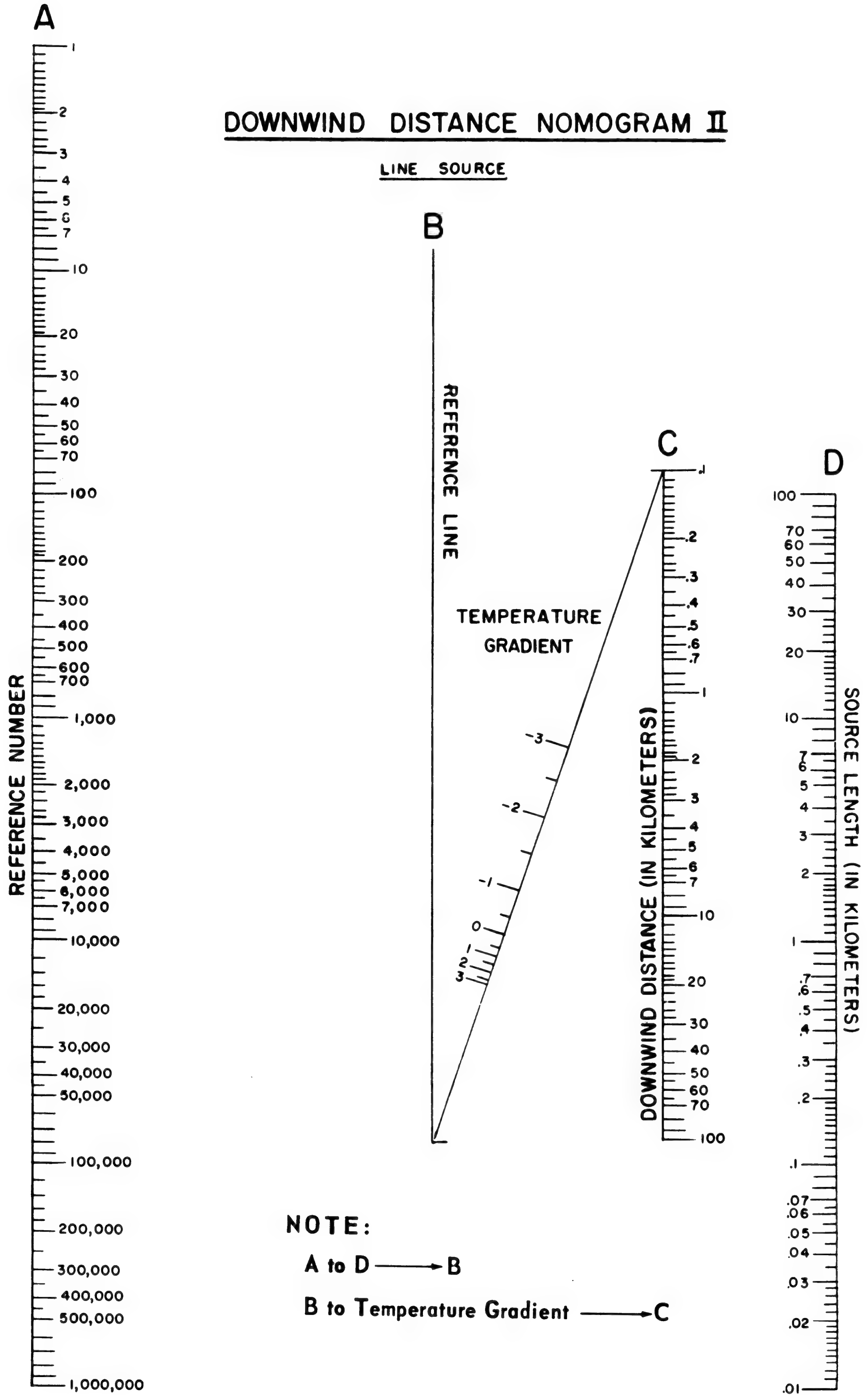


Figure 15. Downwind distance nomogram II.

REFERENCE BOOK

CHEMICAL AND BIOLOGICAL WEAPON EMPLOYMENT

U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE
Fort Leavenworth, Kansas

1 May 1968

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CHAPTER 2
TOXIC CHEMICAL AGENTS

1. Characteristics and Effects

a. General. The following antipersonnel chemical agents are used for College instruction in chemical weapon employment: nerve agents GB and VX; blister agent HD (mustard); and incapacitating agent BZ. Actual or assumed characteristics of these agents are described in the following paragraphs for instructional purposes only and are summarized in figure 1.

b. Nerve Agent GB. GB is a quick acting, nonpersistent lethal agent that produces casualties primarily by inhalation.

(1) Inhalation effects. Inhaled GB vapor can produce casualties within minutes. As an example, 50 percent of a group of unprotected troops engaged in mild activity, breathing at the rate of about 15 liters per minute, and exposed to 70 milligrams of GB per cubic meter of air for 1 minute will probably die if they do not receive medical treatment in time. This is the median lethal dosage (50) and is expressed as 70 mg-min/m^3. For troops engaged in activities that increase their breathing rate, the median lethal dosage can be as low as 20 mg-min/m^3. The median incapacitating dosage of GB vapor by inhalation is about 35 mg-min/m^3 for troops engaged in mild activity. Incapacitating effects consist of nausea, vomiting, diarrhea, and difficulty with vision, followed by muscular twitching, convulsions, and partial paralysis. Dosages of GB less than the median incapacitating dosage cause general lowering of efficiency, slower reactions, mental confusion, irritability, severe headache, lack of coordination, and dimness of vision due to pinpointing of the eye pupils.

(2) Percutaneous effects. Percutaneous effects refer to those effects produced by the absorption of the agent through the skin. GB vapor absorbed through the skin can produce incapacitating effects. Sufficient GB liquid absorbed through the skin can produce incapacitation or death. The effectiveness of the liquid or vapor depends on the amount absorbed by the body. Absorption varies with the original amount of agent contamination, the skin area exposed and the exposure time, the amount and kind of clothing worn, and the rapidity in removing the contamination and/or contaminated clothing and in decontaminating affected areas of the skin.

(3) Major considerations in the employment of nerve agent GB. The employment of GB is based primarily on achieving casualties by inhalation of the nonpersistent vapor (or aerosol) of the agent. Major considerations in the employment of this agent are:

(a) Time to incapacitate. The onset of incapacitation resulting from inhalation of casualty-producing doses is rapid, the average time being approximately 3 minutes. To allow for the time required for the agent cloud to reach the individual, 10 minutes is used as the mean time to achieve incapacitation. Nonlethal casualties from GB will be incapacitated for 1 to 5 days.

(b) Persistency. Persistency is defined as the length of time an agent remains effective in the target area after dissemination. Nerve agent GB is considered nonpersistent. GB clouds capable of producing significant casualties will dissipate within minutes after dissemination. Some liquid GB will remain in chemical shell or bomb craters for periods of time varying from hours to days, depending on the weather conditions and type of munition. Because of this continuing but not readily discernible threat, GB can also be highly effective in harassing roles by causing exposure to low concentrations of the vapor. Rounds fired sporadically may compel the enemy to wear protective masks and clothing for prolonged periods, thereby impairing his effectiveness as a result of fatigue, heat stress, discomfort, and decrease in perception.

(c) Level of protection. The weapon system requirements for positive neutralization of masked personnel by GB are too great to be supported except for important point or small area targets. A major factor affecting casualties resulting from GB attacks of personnel equipped with masks but unmasked at the time of attack is the time required for enemy troops to mask after first detecting a chemical attack. Therefore, surprise dosage attack is used to establish a dosage sufficient to produce the desired casualties before troops can mask. Casualty levels for surprise dosage attack that are tabulated in the weapon system effects tables (app A) are based on an assumed enemy masking time of 30 seconds. (Refer to FM 3-10 series manuals for operational data for masking times less than 30 seconds.) A total dosage attack is used to build up the dosage over an extended period of time and is normally employed against troops who have no protective masks available. Dosages built up before troops can mask inside foxholes, bunkers, tanks, buildings, and similar structures will generally be less than dosages attained during the same period of time in the open, thereby reducing the effects on occupants from surprise dosage attacks. Total dosage effects are essentially the same inside or outside.

c. Nerve Agent VX. VX is a slow-acting, lethal, persistent agent that produces casualties primarily by absorption of droplets through the skin.

(1) Effects. VX acts on the nerve systems of man; interferes with breathing; and causes convulsions, paralysis, and death.

(2) Major considerations in the employment of nerve agent VX.

(a) General. Agent VX disseminated in droplet (liquid) form provides maximum duration of effectiveness as a lethal casualty threat. VX will remain effective in the target area for several days to a week depending on weather conditions. Because of its low volatility, there is no significant vapor hazard downwind of a contaminated area. Except when disseminated by aircraft spray tanks, meteorological conditions have little effect on the employment of VX, although strong winds may influence the distribution of the agent and heavy rainfall may wash it away or dissipate it.

(b) Employment to cause casualties. Agent VX is appropriate for direct attack of area targets containing masked personnel in the open or in foxholes without overhead protection, for causing severe harassment by the continuing casualty threat of agent droplets on the ground or on equipment, and for creating obstacles to traversing or occupying areas. Casualties produced by agent VX are delayed, occurring at times greater than 1 hour after exposure. Although this agent can be used relatively close to friendly forces, it should not be used on positions that are likely to be occupied by friendly forces within a few days. Because of this continuing hazard, areas in which agent VX has been used should be recorded in a manner similar to minefields or fallout areas so that necessary precautions can be taken.

d. Blister Agent HD. HD, sometimes referred to as mustard, is a persistent slow-acting agent that produces casualties through both its vapor and liquid effects.

(1) Vapor effects.

(a) The initial disabling effect of HD vapor on unmasked troops will be injuries to the eyes. Temporary blindness can be caused by vapor dosages that are insufficient to produce respiratory damage or skin burns. However, skin burns account for most injuries to masked troops. The vapor dosages and the time required to produce casualties (4 to 24 hours) vary with the atmospheric conditions of temperature and humidity and with the amount of moisture on the skin. Depending on their severity, skin burns can limit or entirely prevent movement of the limbs or of the entire body.

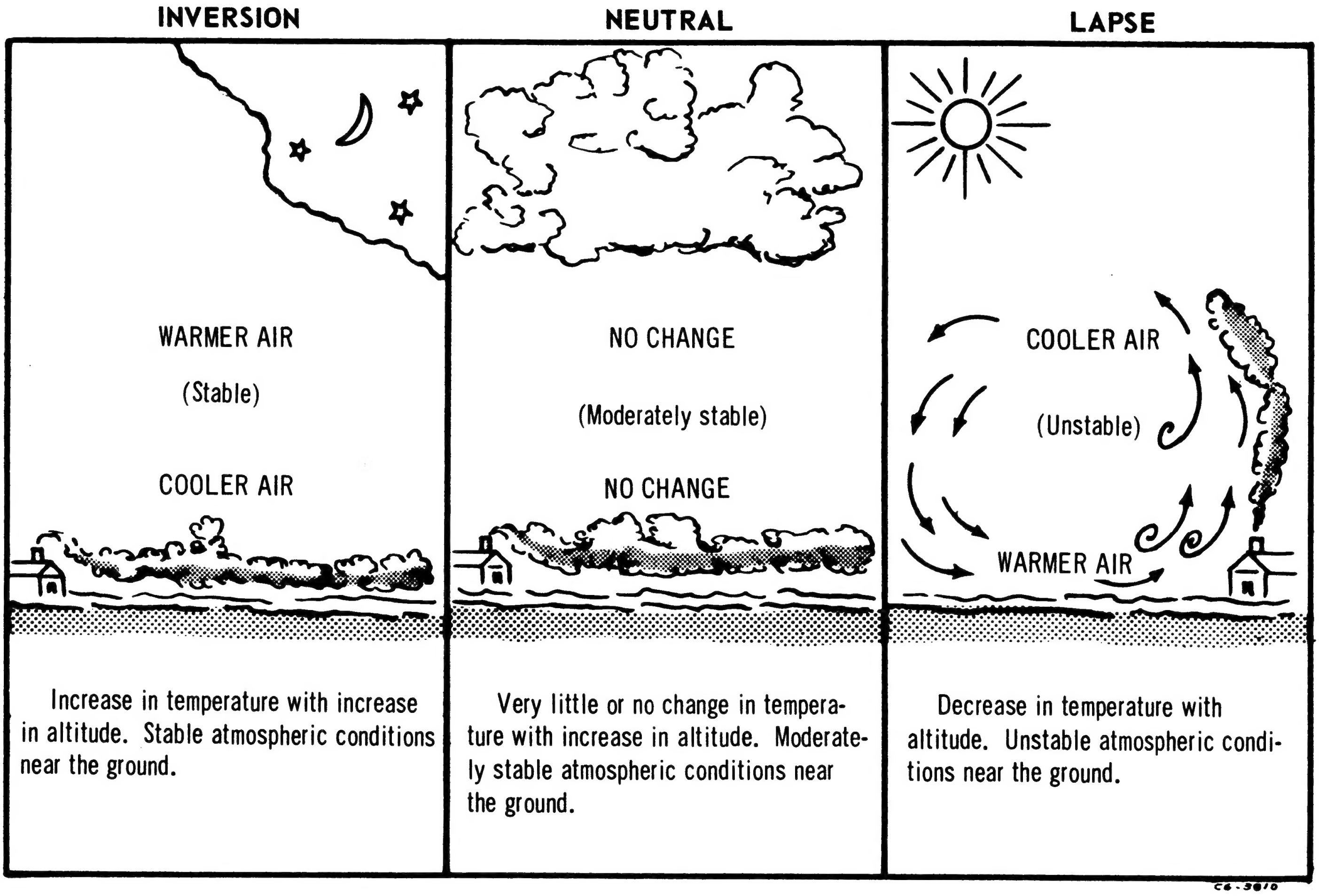

Figure 2. Temperature gradients.

Surprise dosage GB attacks are influenced only slightly by the temperature gradient except when made with the spray tank. Downwind vapor hazards to both enemy and friendly forces will be most significant during inversion and neutral conditions. Employment of VX is not affected by the temperature gradient.

Temperature gradients	Time
1. Inversion	From sunset to sunrise.
2. Neutral	2 hours before sunset to sunset, sunrise to 2 hours after sunrise, or any time windspeed is 15 kmph or greater.
3. Lapse	2 hours after sunrise to 2 hours before sunset.

Figure 3. Estimated times that temperature gradients will prevail. (Use when meteorological data are not available.)

(3) When actual or predicted meteorological conditions are not available for a target analysis, 70° F is used for temperature, 9 kmph is used as windspeed, and the temperature gradient is approximated from figure 3.

d. Windspeed and Direction.

(1) Air moving over the earth's surface sets up eddies, or mechanical turbulences, that act to dissipate a chemical cloud. A condition of calm will limit the merging of the individual gas clouds. Both of these conditions may reduce the effectiveness of a chemical agent attack. High winds increase the rate of evaporation of HD and dissipate chemical clouds more rapidly than low winds. Moderate winds are desirable for chemical employment. Large-area nonpersistent chemical attacks are most effective in winds not exceeding 28 kmph. Small-area nonpersistent chemical attacks with rockets or shell are most effective in winds not exceeding 9 kmph. However, if the concentration of chemical agent can be established quickly, the effects of high windspeed can be partially offset.

CHAPTER 4
EMPLOYMENT OF BIOLOGICAL AGENTS

1. General

a. Antipersonnel biological agents are micro-organisms that produce disease in man. These agents can be used to incapacitate or kill enemy troops through disease. They may cause large numbers of casualties over vast areas and could require the enemy to use many personnel and great quantities of supplies and equipment to treat and handle the casualties. Many square kilometers can be effectively covered from a single aircraft or missile. The search capability of biological agent clouds and the relatively small dose required to cause infection among troops give biological munitions the capability of covering large areas where targets are not precisely located.

b. A biological attack can occur without warning since biological agents can be disseminated by relatively unobtrusive weapon systems functioning at a considerable distance from the target area and relying upon air movement to carry the agent to the target.

c. Biological agents do not produce effects immediately. An incubation period is required from the time the agent enters the body until it produces disease. Some agents produce the desired casualty levels within a few days, whereas others may require more time to produce useful casualty levels. A variety of effects may be produced, varying from incapacitation with few deaths to a high percentage of deaths, depending on the type of agent.

2. Methods of Dissemination

a. The basic method of disseminating antipersonnel biological agents is the generation of aerosols by explosive bomblets and spray devices. Because exposure to sunlight increases the rate at which most biological agent aerosols die and thereby reduces their area coverage, night is the preferable time for most biological attacks. However, if troop safety is a problem, an attack may be made near sunrise to reduce the distance downwind that a hazard to friendly forces will extend. Conversely, to extend the downwind cloud travel and the area coverage from spray attack, a biological agent may be employed soon after sundown.

b. Missile-delivered Biological Munitions. Missile-delivered biological munitions are used for attack of large-area targets. A typical biological missile system consists of the following components:

(1) A missile vehicle and its launching equipment.

(2) A warhead that can be opened at a predetermined height to release biological bomblets over the target area. The warhead is shipped separately for assembly to a missile at the launching site.

(3) A warhead shipping container equipped with a heating-cooling element and a temperature control unit.

(4) Biological bomblets consisting of an agent container and a central burster that functions on impact. The bomblets have vanes that cause them to rotate in flight, thereby achieving lateral dispersion during their free fall and resulting in random distribution as a circular pattern.

c. Aircraft Spray Tank. Biological agents released from an aircraft spray tank cover a large area downwind of the line of release. A typical spray tank consists of the following components:

(1) An agent reservoir section that is shipped separately in an insulated shipping and storage container equipped with a heating-cooling element and a temperature control unit.

(2) A discharge nozzle assembly that can be mechanically adjusted to vary the agent flow rate.

Table 1. Chemical Weapons Data

1	2	3	4	5	6	7	8	9	10	11	12	13
Delivery system	Range (meters)		Agent	Munition	No of weapons per delivery unit	Weapon rate of fire	RT max (meters)[1,2]					Reference (table)
							Fire unit	Total dosage		Surprise dosage		
								Casualty threat		Casualty threat		
	Min	Max						10%	30%	10%	30%	
4.2-in mortar	180	4,500	HD	Cartridge, M2A1	4/Plat	50 rd/3 min 105 rd/15 min						18 19
105-mm howitzer		11,100	GB	Cartridge, M360	6/btry	5 rd/30 sec 30 rd/3 min 66 rd/15 min	1 btry[3]	200	100	100	50	2
							1 bn[3]	300	300	200	100	3
			HD	Cartridge, M60								18 19
155-mm howitzer		14,600	GB	Projectile, M121	6/btry	2 rd/30 sec 12 rd/3 min 24 rd/15 min	1 btry[3]	300	200	100	0	4
							1 bn[3]	500	400	300	100	5
			HD	Projectile, M110								18 19
			VX[4]	Projectile, M121			1 btry[3]	400	200	NA	NA	13
							1 bn[3]	500	400			
8-in howitzer		16,800	GB	Projectile, M426	4/btry	1 rd/30 sec 4 rd/3 min 10 rd/15 min	1 btry[3]	300	200	200	0	6
							1 bn[3]	500	400	300	100	7
			VX[4]				1 btry[3]	400	200	NA	NA	14
							1 bn[3]	500	400			
115-mm multiple rocket launcher, M91	2,740	10,600	GB[4]	Rocket, M55 (THE BOLT)		45 rkt/lchr/15 sec	1 lchr	1,000	750	500	200	8
							3 lchr	1,000	1,000	750	400	
							6 lchr	1,000	1,000	1,000	750	
							9 lchr	1,000	1,000	1,000	1,000	
			VX[4]				1 lchr	300	0	NA	NA	15
							3 lchr	750	300			
							6 lchr	1,000	400			
							9 lchr	1,000	750			
762-mm rocket, Honest John	8,500	38,000	GB[4]	Warhead, M190 (M139 bomblets)	2/btry	2 rkt/lchr/hr	1 lchr	600	600	600	400	9
							2 lchr	600	600	600	400	
Sergeant missile	46,000	139,000	GB[4]	Warhead, M212 (M139 bomblets)	2/bn	2 msl/lchr/hr	1 msl	600	400	600	200	10
							2 msl	600	600	600	400	
Aircraft	Dependent on type aircraft		GB[4]	Bomb, MC-1, 750-lb	Dependent on type aircraft		1 bomb	50				11
							6 bombs	300	200	300	50	
							12 bombs	500	300	400	200	
							24 bombs	500	300	500	300	
			GB[4]	Spray tank, 100-gal			1 spray tank 2 spray tanks	RT max=750 meters (one-half effective spray release line length)				12
			VX[4]				1 spray tank	RT max=500 meters (one-half effective spray release line length)				16
			BZ[4]	Bomb, 150-lb Bomb, 700-lb								17

[1]RT max is largest target radius for which indicated casualty threat is tabulated for appropriate fire unit. Division of target into subtargets NOT considered.

[2]All windspeeds, temperature gradients, and protection categories considered.

[3]RT max computed for maximum number of volleys for which data are tabulated.

[4]Weapon system capabilities derived from tables composed of hypothetical data for INSTRUCTIONAL PURPOSES ONLY at the U. S. Army Command and General Staff College. For actual data, refer to FM 3-10.

Table 2. Estimated Fractional Casualty Threat From 105-mm Howitzer, GB Projectile, Battery Fire[1 2]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target radius–radius of effect (meters)	Range to target (km)	No of volleys	Windspeed[3]											
			4 kmph				9 kmph				28 kmph			
			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]		
				I	N	L		I	N	L		I	N	L
50	<7.5	1	.10	.25	.20	.15	.10	.15	.10	.10				
		2	.20	.45	.40	.30	.15	.30	.25	.20		.10	.05	.05
		3	.30	.60	.60	.35	.30	.50	.45	.30	.10	.20	.15	.10
		4	.30	.75	.70	.45	.30	.55	.45	.35	.10	.25	.20	.10
		5	.35	.90	.85	.55	.35	.60	.50	.40	.15	.30	.25	.15
	>7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.15	.30	.25	.15	.10	.20	.15	.10		.05	.05	
		3	.15	.30	.30	.25	.10	.20	.20	.15		.10	.05	.05
		4	.20	.40	.35	.25	.15	.30	.30	.15	.05	.15	.15	.05
		5	.25	.45	.45	.30	.25	.40	.35	.25	.10	.20	.20	.10
100	<7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.10	.30	.30	.15	.10	.20	.15	.10				
		3	.15	.40	.35	.20	.15	.25	.25	.15	.05	.10	.05	
		4	.15	.40	.35	.30	.15	.30	.30	.15	.05	.10	.10	.05
		5	.20	.45	.40	.35	.20	.35	.35	.20	.10	.15	.15	.10
	≥7.5	1	.05	.10	.10	.05		.05	.05					
		2	.10	.20	.20	.10	.05	.15	.10	.05				
		3	.10	.25	.25	.15	.10	.15	.15	.10		.05	.05	
		4	.10	.30	.25	.20	.10	.25	.20	.15		.10	.05	
		5	.15	.35	.30	.25	.15	.30	.25	.15	.05	.15	.10	.05
200	Any	1		.05	.05									
		2		.10	.10	.05		.05	.05					
		3	.05	.15	.15	.05		.10	.05					
		4	.05	.15	.15	.10		.10	.10					
		5	.05	.20	.20	.10	.05	.15	.10	.05				

[1]Blank spaces indicate fractional casualties are below 0.05.

[2]If the target is predominately wooded, use a windspeed of 4 kmph and neutral temperature gradient for total dose attack; use a windspeed of 4 kmph for surprise attack.

[3]For windspeeds other than those shown, use data given for the nearest windspeed.

[4]Multiply the figures given in the table by the appropriate factor to obtain the fractional casualties from surprise dose attack:

Troops in open foxholes:	0.7
Troops in covered foxholes or bunkers:	0.6

[5]I = inversion, N = neutral, L = lapse.